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BIOLOGICAL, WATER QUALITY, AND AQUATIC HABITAT RESPONSES TO WILDFIRE IN THE MIDDLE FORK OF THE SALMON RIVER AND ITS TRIBUTARIES

Final Report

By

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Submitted to

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INTRODUCTION

The purpose of this study is to define and monitor the effects of fire on the Middle Fork of the Salmon River and its tributaries. It also provides basic information on the effects of fires on streams of various sizes which can be used to guide management of fire-perturbed watersheds in the Intermountain Region.

The Mortar Creek Fire on the Middle Fork of the Salmon River, Idaho began as an abandoned camp fire on July 25, 1979 and, by the time it was declared out on August 20, it burned over 26,000 ha. Due to extreme burning conditions resulting from drought effects and heavy accumulation of fuels, the fire spread rapidly and reached an estimated intensity of well over 30,000 BTU/S/ft (Byrams Intensity: Personal Communication from T.C. Harbour to J.T. Brock). However, fire intensity varied resulting in a mosaic of burned areas ranging from little effect to severe (= hot burn) (Fig. 1). The burned area extended along 40 km of the mainstream and encompassed several important tributaries. The most extensively and severely affected watershed was Little Loon Creek.

Our approach was to establish a series of study sites representing an array of burned and unburned (control) watersheds of different sizes (Table 1). We concentrated on streams in severely burned areas because they show the maximum effect of the fire; the control sites provide a measure of conditions in the absence of fire. The basic plan was to evaluate a full range of ecosystem-level parameters (Table 5) beginning

Figure 1 . Location of study sites for evaluation of the effects of the Mortar Creek Fire on the Middle Fork of the Salmon River. M = mainstream sites; T = tributary sites; C = control (unburned) sites (8 total).

Middle Fork Mainstream Sites	Middle Fork Tributaries	
M-1 Dagger Falls (C)	T-1 Indian Creek (C)	T-7 Little Loon Creek
M-2 Above Indian Creek	T-2 E. Fk. Indian Creek (C)	T-8 Char Creek
M-3 Above Little Creek	T-3 Pungo Creek (C)	T-9 W. Fk. Little Loon Creek
M-4 At Pine Creek Flat	T-4 Teapot Creek (C)	T-10 E. Fk. Little Loon Creek
M-5 Above Big Loon Creek	T-5 Marble Creek (C)	T-11 White Creek (C)
M-6 Above Mouth	T-6 Little Creek	T-12 Big Loon Creek (C)

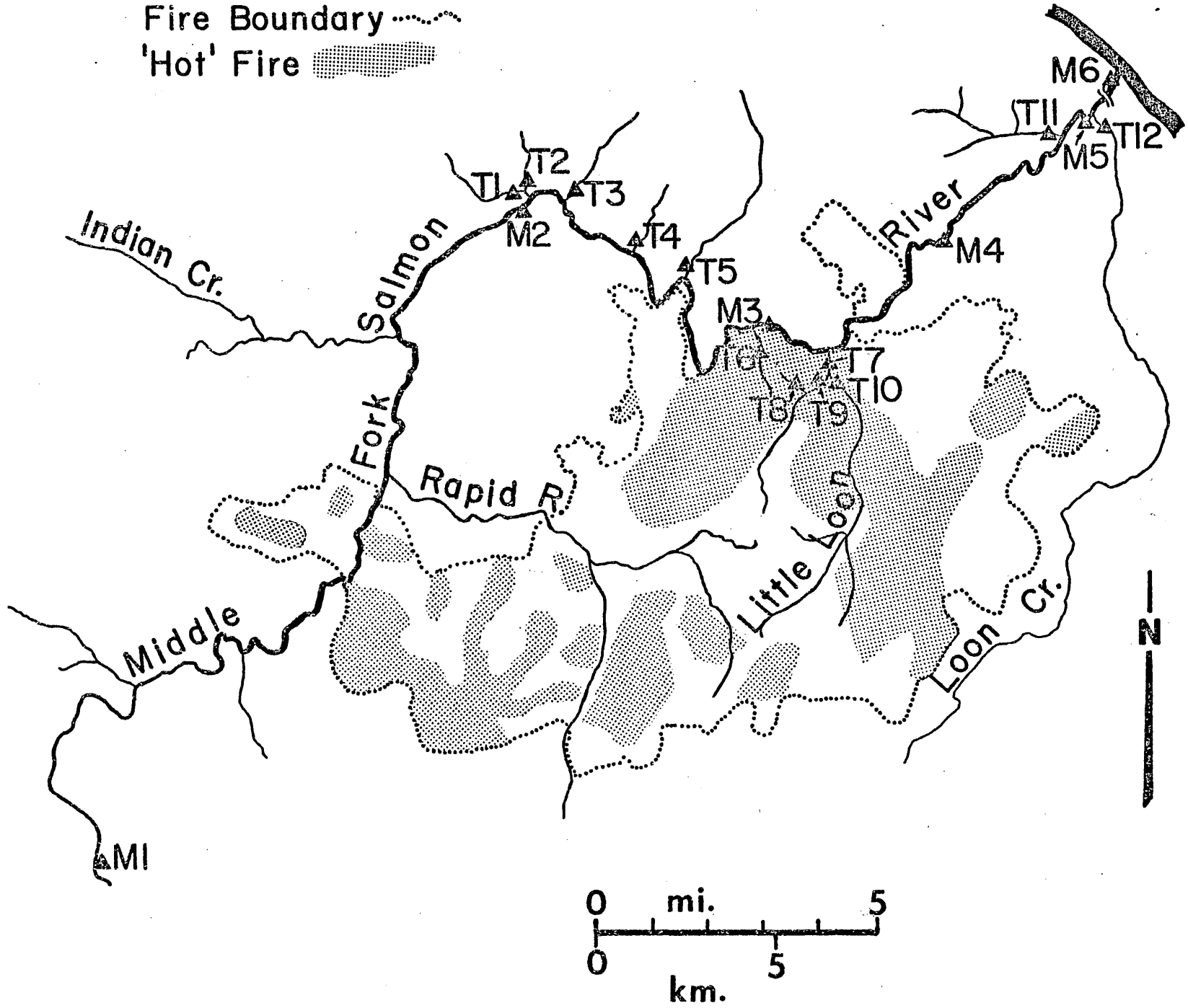

Fire Boundary
'Hot' Fire
Indian Cr.
Salmon River
Middle Fork
Rapid R.
Little Loon
Loon Cr.
M1
M2
M3
M4
M5
M6
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
N
0 mi. 5
0 5
km.

Table 1. Coverage of stream sizes for the Mortar Creek Fire Study.

Control Streams	Order	Stream Link	Burn Streams	Order	Stream Link
Tributaries					
Teapot	(1)	1	Char	(2)	2
Pungo	(2)	10	Little	(2)	7
E. Fk. Indian	(3)	12			
White	(4)	24	W. Fk. L. Loon	(4)	24
Indian	(4)	89	E. Fk. L. Loon	(4)	105
Marble	(5)	262	Little Loon	(5)	132
Loon	(6)	903			
Mainstream					
Dagger	(6)	559	Above Indian	(6)	1218
			Below Little	(6)	1615
			At Pine Flat	(6)	1817
			Above Loon	(6)	1887
			At Mouth	(7)	5412

as soon after the fire as possible and again following spring runoff and to monitor nutrient and sediment dynamics throughout the runoff period. This sampling scheme allowed us to partition the effects of the fire into those which were immediate (heat, particulate fallout, etc.) and those which were secondary, and to calculate materials loading budgets for streams of different sizes. In keeping with this plan, a full set of abiotic-biotic measurements were made in autumn 1979 (October 27-November 5) and sediment-nutrient conditions were measured on four occasions (March 2-6, April 21-28, May 11-23, June 14-16) during spring 1980. Since many of the secondary effects (e.g., increased runoff, erosion, scouring) were expected to be associated with spring runoff or summer storms, a second full set of samples was collected in late summer 1980 (July 21-August 2).

Description of the Study Area

The Middle Fork of the Salmon River flows through a remote area of central Idaho and for most of its length lies within the River of No Return Wilderness Area. Except for an occasional caretaker associated with private inholdings, there are no permanent human inhabitants and the nearest services are located 80 to 160 km by air from the river. Main use of the river is by recreationists, mostly in rafts, and is restricted largely to the summer.

Principal access to the area is by a dirt road to Dagger Falls at the upstream edge of the Wilderness Area (open only in summer and fall), by non-motorized boats along the mainstream, and by airplane to a half-dozen landing strips scattered along the river. The headwaters of a few of the tributaries can be reached by means of

unimproved roads but most of the tributaries are accessible only by trail.

The topography is extremely rugged with elevations ranging from 3150 m at Twin Peaks to 1220 m on the Middle Fork at the mouth of Loon Creek. The streams have high to medium gradients with steep side slopes. The area is underlain by Challis Volcanics which have been intruded by various phases of the Idaho Batholith. Challis Volcanics are comprised of tuffs and flows of rhyolitic to andesitic rock of Eocene age (Ross 1934, Cater et al. 1973, Knowles and Bennett 1978). The Idaho Batholith is a pluton of granodiorite and quartz monzonite with lesser amounts of diorite which formed during the Cretaceous. The Casto Pluton, a pink granite of Tertiary age, intrudes the Challis Volcanics.

The stream sites examined during this study lie on a mixture of Idaho Batholith and Challis Volcanics rocks. But the conditions are complex with most drainages underlain by several parent rock types (Table 2). Evidence of glacial activity (Quaternary) is widespread but relatively minor in extent. Some of the stream courses contain glacial deposits and stream terrace gravels. Development of soils is still in the very early stages.

Climate in the area varies markedly with elevation. At the higher elevations snow usually begins to accumulate by late October and remains on the ground through May. Snow accumulation begins several weeks later at the lower elevations and may disappear by early April. Most of the precipitation falls in the winter as snow although summer thunderstorms can deliver substantial amounts on a local basis. Quantities range from 38 to 50 cm in the valleys to

Table 2. Drainage basin characteristics of Mortar Creek Fire Study sites listed in order of downstream distance along Middle Fork from Dagger Falls.

Site	Type C = Control B = Burn	Longitude	Latitude	River Distance from Dagger Km	Drainage Area Km^2	Drainage Aspect	Maximum Stream Elev. in Drainage m	Station Elevation m	Drop m	Drainage Rock Type
MF Dagger	C	115°16'59"	44°31'43"	0	-	NW	2623	1768	855	Batholith (quartz monzonite, granite)
MF above Indian Ck	B	115° 6'33"	44°45'29"	40.4	-	NE	2623	1426	1197	Batholith (quartz monzonite, granite)
Indian Ck	C	115° 6'27"	44°46' 2"	42.6	212.7	SE	2318	1414	904	Volcanics, quartz monzonite
East Fk Indian Ck	C	115° 5'32"	44°46'15"	42.6	17.3	SW	2318	1413	905	Volcanics
Pungo Ck	C	115° 4'21"	44°45'56"	44.6	13.8	S	2318	1396	922	Quartzite, granite, volcanics
Teapot Ck	C	115° 2'37"	44°45'10"	45.9	2.9	S	2342	1390	952	Granite, quartzite
Marble Ck	C	115° 1' 0"	44°44'38"	51.5	298.8	S	2623	1344	1279	Volcanics, granite
Little Ck	B	114°59'31"	44°43'11"	56.0	5.1	NW	2403	1408	995	Quartz monzonite, granite
MF at Little Ck Bridge	B	114°59'53"	44°43'27"	56.0	1,990	NE	2623	1311	1312	
Little Loon Ck	B	114°56'17"	44°43'45"	63.6	86.5	NW	2562	1286	1276	Granite, quartz, diorite, volcanics
Char Ck	B	114°56' 8"	44°42'31"	63.6	3.2	NE	2342	1356	986	Granite
West Fk Little Loon Ck	B	114°56' 3"	44°42'35"	63.6	20.7	NE	2446	1341	1105	Granite, quartzite, dacite
East Fk Little Loon Ck	B	114°55'58"	44°42'35"	63.6	84.0	NW	2562	1329	1233	Granite, quartz, diorite, volcanics
MF at Pine Ck Flat	B	114°53'42"	44°45'47"	70.2	-	NE	2623	1298	1325	
White Ck	C	114°50'39"	44°47'29"	76.3	11.3	SE	2330	1244	1086	Granite, volcanics
MF above Loon Ck	B	114°48'43"	44°48'26"	80.0	-	NE	2623	1219	1404	
Loon Ck	C	114°48'35"	44°48'25"	80.0	-	NW	2623	1219	1404	Granite, quartz monzonite, volcanics
MF at Mouth	B	114°35'40"	45°17'44"	155.3	-	NE	2623	914	1709	

76 to 100 cm on the mountains. Air temperatures range from well below freezing in the winter to around 27°C in summer. There is a marked diel temperature range amounting to as much as 30°C.

The predominant types of vegetation vary with elevation. Ridge tops and valley side slopes are inhabited mainly by pine or fir. Lower down, sagebrush (Artemisia sp.) and grasses are common especially on south-facing slopes along the main river. Tributaries frequently support dense riparian growth of alder (Alnus sp), water birch (Betula occidentalis), cottonwood (Populus balsamifera) and willow (Salix sp.). The conifers themselves show a change with elevation shifting from subalpine fir (Abies lasiocarpa) and whitebark pine (Pinus albicaulis) at higher elevations to Douglas fir (Pseudotsuga Menziesii) and aspen (Populus tremuloides) at mid-elevation, and Ponderosa pine (Pinus Ponderosa) at the lower elevations.

General Characteristics of the Study Streams

Various measures may be used to delimit stream size including: order, link, and drainage area. In general, streams of 1st to 4th order having <25 external links and draining an area of <25 km^2 were considered small, those of 4th to 6th order, 25-1000 links and 25-1000 km^2 drainage area were designated as medium-sized streams (Table 2). Pertinent physical characteristics of the study stream drainage basins are shown in Table 2. The small tributaries had channel slopes of 8-18% compared to 2 to 5% for medium-sized tributaries and 1-3% for the main river. Other hydraulic characteristics (width, depth, velocity, discharge) at the discharge cross-sections are given for the two extremes of runoff (base flow and peak measured discharge) in Table 3. The only

Table 3. Channel characteristics of Mortar Creek Fire Study sites.*

	Type C = Control B = Burn	Median Bed Material (D_{50}) cm	Slope at Station %	Width m	Depth m	Velocity m	Discharge m^3/s
MF Dagger	C	20	1	24.6-(35.0)	0.48-(1.84)	0.61-	7.2-
MF above Indian Ck	B	19	1	50.5-55.0	0.60-1.31	0.68-1.80	21.0-130.6
Indian Ck	C	14	2	8.0-19.0	0.26-0.63	0.73-1.81	1.5-21.8
East Fk Indian Ck	C	10	9	0.8-5.0	0.16-0.22	0.26-0.95	0.10-0.94
Pungo Ck	C	10	11	1.5-4.5	0.11-0.26	0.29-1.11	0.07-0.68
Teapot Ck	C	10	18	1.1-1.7	0.05-0.13	0.04-0.54	0.004-0.089
Marble Ck	C	12	1.5	13.0-18.8	0.24-0.88	0.30-2.07	1.2-23.7
Little Ck	B	8	14	0.2-2.5	0.04-0.12	0.16-0.86	0.004-0.186
MF at Little Ck Bridge	B	-	1	34.0-50.0	0.62-1.42	0.84-2.23	17.8-148.3
Little Loon Ck	B	9	5	3.7-5.0	0.21-0.52	0.45-1.48	0.40-3.84
Char Ck	B	6	19	0.6-1.5	0.04-0.13	0.06-1.08	0.002-0.212
West Fk Little Loon Ck	B	8	9	1.3-2.5	0.16-0.25	0.24-1.15	0.09-0.64
East Fk Little Loon Ck	B	9	3	4.8-(8.4)	0.18-(0.59)	0.97-	0.31-3.20
MF at Pine Ck Flat	B	14	1	-	-	-	18.2-151.0
White Ck	C	10	8	0.7-2.3	0.05-0.23	0.21-1.15	0.02-0.45
MF above Loon Ck	B	12	1	-	-	-	13.7-151.0
Loon Ck	C	8	2	15.0-(29.3)	0.26-(0.42)	0.44-	2.82-
MF at Mouth	B	22	1	-	-	-	-

*Median Bed Material (D_{50}) value is for intermediate (b) axis. Range of channel characteristics given is for base and peak flow as measured during the study (October 1979-July 1980). Width and depth values in parentheses are bankfull flow measurements estimated during base flow channel surveys. Cross section data for down river Middle Fork sites are not available since they were unwadeable.

continuous discharge record available for the area is for the mainstream at Middle Fork Lodge (USGS Station No. 13309220; Fig. 2). These data show that the discharge pattern is dominated by spring runoff with the period of high water extending over 4 months, with base flows generally found over the remaining 8 months. The relatively brief period of continuous record (1974-1980) makes calculation of recurrence intervals rather tenuous but it appears that 1980 was a normal ("average") flow year.

The seasonal pattern of stream temperatures is typical of Rocky Mountain streams (Fig. 3). Values remain at or near zero for several months in late fall and winter and then rise to their maxima in July and August. Temperature data collected for the individual stations are given in Table 4. The record is incomplete because of infrequent readings due to the remoteness of the area, inaccessibility and malfunctions during the period of high water, and the lack of funds for a post-summer trip to record summer maxima. However, the records do not reveal any major differences between the control and burn study sites. The burn sites may have been a few degrees warmer than the control sites during the summer. But there were no major departures from the norm.

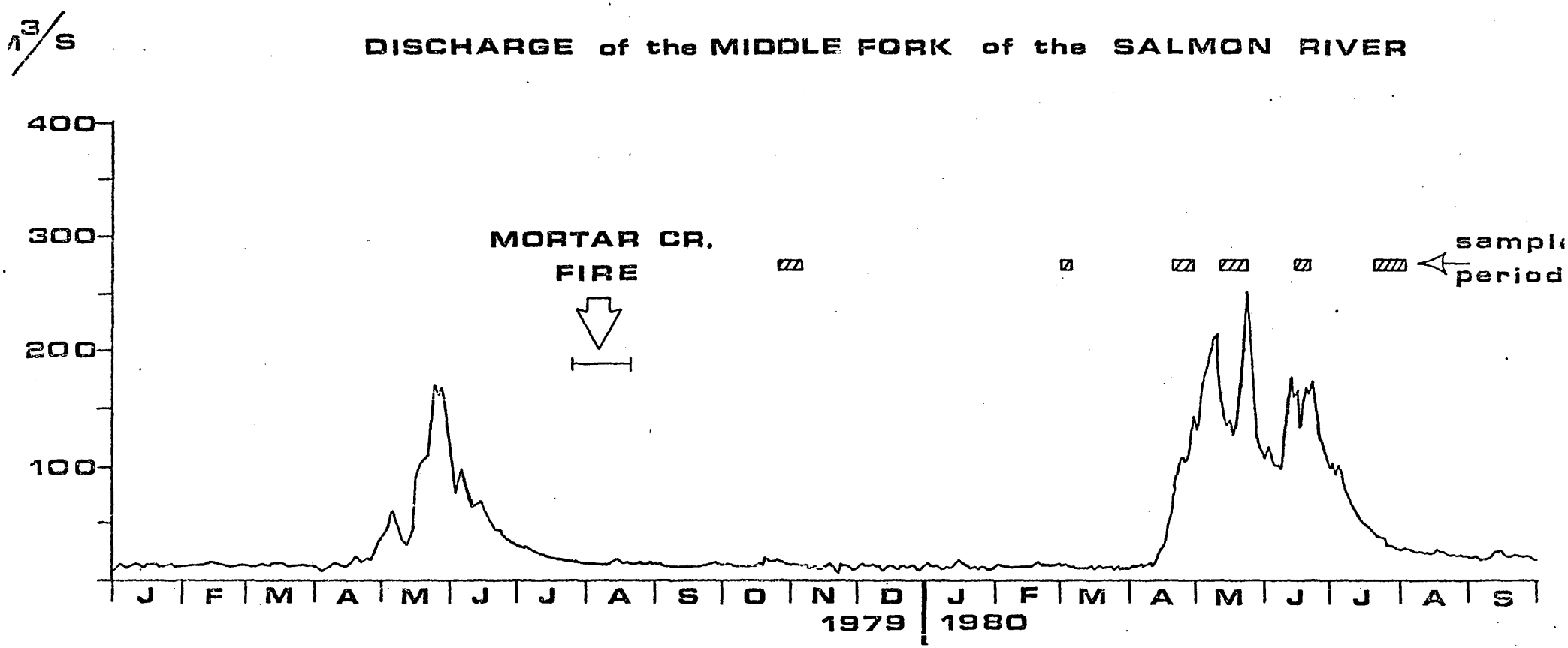


Figure 2. Occurrence of the Mortar Creek Fire and timing of sampling periods in relationship to discharge relationships of the Middle Fork of the Salmon River. (Discharge values are from U.S.G.S. records.)

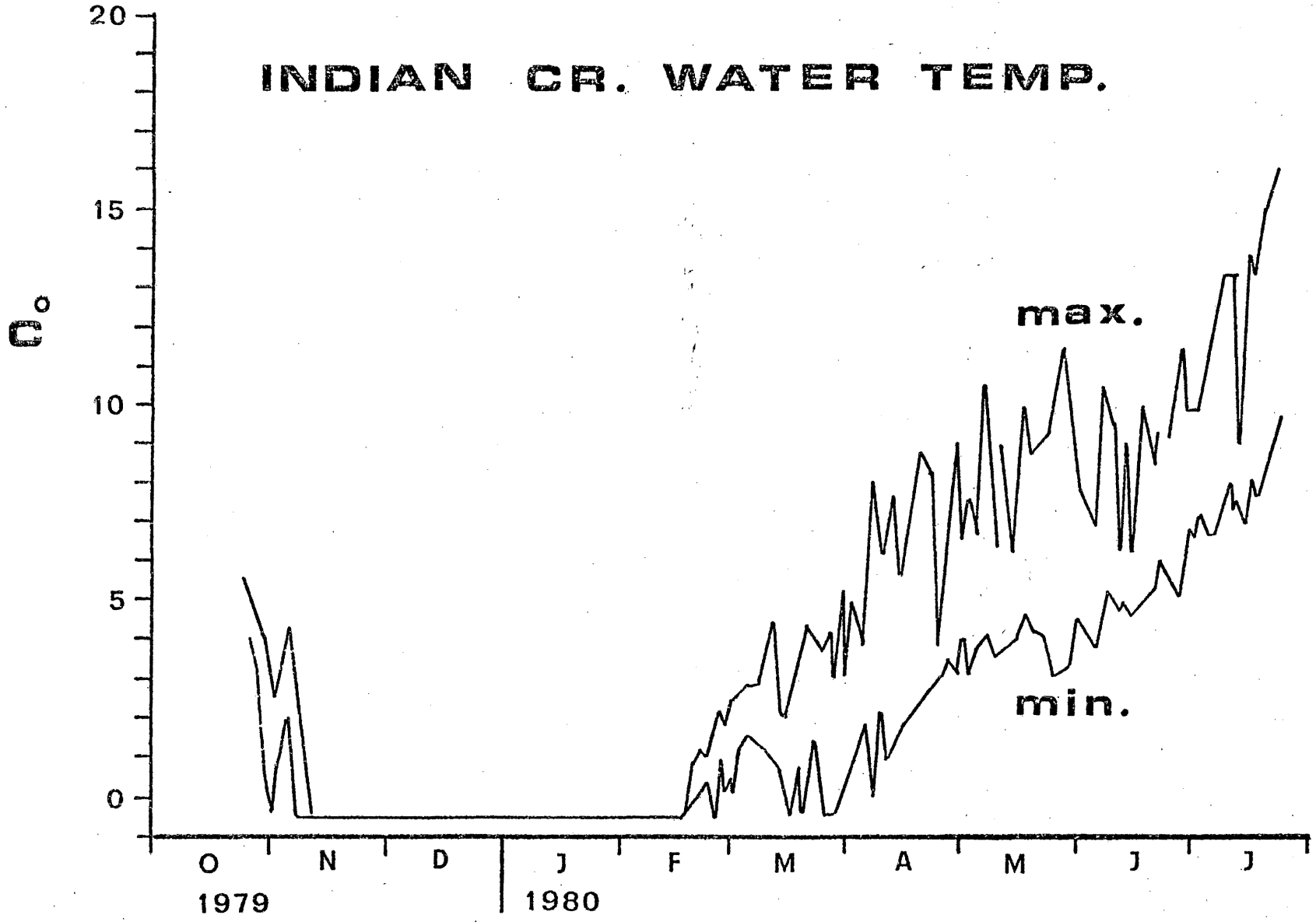


Figure 3. Daily records of maximum and minimum water temperatures at Indian Creek. Similar records planned for Little and Little Loon Creeks were not obtained due to malfunctioning of the recorders.

Table 4. Mortar Creek Fire study temperature records for 1980 (°C).

Site	March			April			May			June			July		
	Pres	Max	Min	Pres	Max	Min	Pres	Max	Min	Pres	Max	Min	Pres	Max	Min
Teapot (C)	3	NI	NI	NR	NI	NI	NR	NI	NI	NR	NI	NI	7	NI	NI
Char (B)	2	NI	NI	2	NI	NI	NR	NI	NI	9	NI	NI	11	13	RM
Pungo (C)	2	5	2	RM	RM	RM	5	7	0	5	6	4	11	RM	RM
Little (B)	3	NI	NI	NI	NI	NI	8	NI	NI	NI	NI	NI	16	NI	NI
White (C)	3	6	2	7	8	2	11	12	0	9	11	6	16	17	8
W.Fk. Little Loon (B)	4	7	0	7	RI	RI	9	RM	3	11	12	7	12	15	6
Indian (C)	3	6	0	8	10	0	9	6	3	7	12	5	11	16	6
E.Fk. Little Loon (B)	2	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
Marble (C)	0	6	0	SI	SI	SI	8	SI	SI	SI	SI	SI	13	RM	RM
Little Loon (B)	3	6	0	8	8	0	8	10	3	12	14	2	18	RM	RM
Loon (C)	2	5	0	9	RI	RI	RI	RI	RI	RM	RM	RM	17	RM	RM
MF Dagger (C)	SI	SI	SI	SI	SI	SI	SI	SI	SI	6	RM	RM	12	RM	RM
MF above Indian (B)	1	4	0	4	7	0	6	8	5	7	10	4	16	RM	RM
MF at Pine (B)	2	5	-1	RI	RI	RI	RI	RI	RI	RI	RI	RI	18	RB	RB

NI - Recorder not installed
SI - Site inaccessible
RI - Recorder inaccessible - high water
RM - Recorder malfunction
NR - Not recorded

METHODS

The procedures used in the collection and analysis of samples are summarized in Table 5. Where published techniques were followed, the references are provided. Unpublished procedures and additional details are described below. These relate to sections 4, 5, and 7 in Table 5.

Transported and Stored Organic Matter

Our Middle Fork streams research program included collection of samples for qualitative and quantitative analyses of benthic as well as transported organic material. Prior to freezing, the material was separated in the field into coarse (> 1 mm), and fine (> 0.052 mm and < 1.00 mm) categories, with an additional unfractioned sample collected from the transport. Wet and dry subsamples were preserved and retained for reference. While consumer growth is thought to be the ultimate test of the nutritive quality of organic material, several chemical measures have been found useful for characterizing organic material. Organic matter determinations for concentration or standing crop destroy the entire sample, hence separate collections were made to provide sufficient material for qualitative analysis. The measures of organic matter quality employed in this study include visual examination, percent organic, chlorophyll content, and elemental composition (C, H, and N). The procedures used for the evaluation of organic matter are outlined in Table 6.

Table 5. Summary of study parameters, sampling methods, and analytical procedures for evaluating the effects of the Mortar Creek fire on streams in the Middle Fork drainage of the Salmon River.

1. Discharge	Velocity-depth profiles; Price or Ott Current Meters; established transects.	Calculation (Bovee and Milhous 1978)
2. Temperature	Recording thermographs at 3 selected sites Maximum-minimum recording thermometers at all others.	Direct observation
3. Water Quality	Composited "grab" samples	
pH		Coleman Null-balance Meter (APHA 1976)
Specific Conductance		Beckman or Yellow-Springs Wheatstone Bridge (APHA 1976)
Alkalinity		Gran Titration (Talling 1973)
Dissolved Organic Carbon		Oceanography International Carbon Analyzer, (Menzel and Vaccaro 1964)
Specific Ions		
Calcium		Atomic Absorbtion Spectrophotometer
Magnesium		Atomic Abosrbtion Spectrophotometer
Nitrogen (NO_2 + NO_3)		Cadmium Reduction (APHA in press; EPA 1979)
Phosphorus (ortho)		Isobutanol Extraction followed by Stannous Chloride Method (Strickland and Parsons 1965; Chamberlain and Shapiro 1969)
Potassium		Atomic Absorbtion Spectrophotometer
Sodium		Atomic Absorbtion Spectrophotometer
Sulfate		Tubidimetric Method using Hach Sulfaver IV Reagent (APHA 1976)

Table 5, continued.

4. Transport (materials carried in suspension by stream)			
Quantity			
Partitioned into 3 particle sizes	>1mm	River - conical net with flowmeter,	Dried at 60°C, weighed; combusted 550°C, reweighed.
	.052-1.0 mm	Tributaries - siphon hose and net.	
	.052 mm	Depth integrating sampler (D-48, D-75Q, D-77), field filtration onto tared glass fiber filters.	
Quality			
% Organic	Same as Above		Ash-free dry weight - total dry determined as above.
Chlorophyll a			Acetone extraction; spectrophotometric or fluorometric assay with correction for phaeopigments (Lorenzen 1966, Yentsch and Menzel 1963).
Carbon:Nitrogen ratio			Carlo-Erba C-H-N Analyzer
Activity (Fine category only)			Oxygen uptake in respirometer using YSI probes.
5. Storage (Materials deposited on stream bottom)			
Total	>1 cm: "Pebble Counts" (Wolman 1954; Leopold 1970) .05 mm - 1 cm: volume-weight of materials vacuumed from known area along a transect.		Measure a,b,c-axes; caluclate rock volume. Imhoff Cones; Volumes converted to weights using density of 2.65
Organic	Qualitative sample for % OM.		Partitioned into 3 particle sizes.
Inorganic			Dried at 60°C, weighed, combusted at 550°C, reweighed. Convert to amount from knowledge of total weight. Calculate inorganic portion by difference.

Table 5, continued.

6. Benthic Organisms Invertebrates and associated detritus	Collect 5 Surber Samples (Welch 1948) or cobble stones at each site.	Measure a, b, c-axes of rocks. Separate invertebrates into functional groups (Merritt and Cummins 1978), count and weigh (or measure length). Determine Biotic Condition Index. Determine AFDW of detritus.
Periphyton Standing Crops	Scrape known area of rocks; collect scrapings on filter.	Determine chlorophyll (as in 4) and AFDW.
Autotrophic Potential	Colonization of standard substrate (tiles) over known time intervals. 4 per site · per time. Integrate total insolation for interval using hydroxyethyl cellulose (Dixon and Davies 1975)	Measure oxygen change in metabochamber and AFDW of periphyton.

Table 6. Outline for Processing Transport and Benthic Organic Matter Samples: Quantitative and Qualitative Methods.

I. Storage and preparation

All samples are frozen as soon as possible after collection for a period of not less than 24 h. Prior to processing, they are thawed in a refrigerator at 4 C.

II. Processing

A. Quantitative analysis includes measurement of chlorophyll concentration followed by dry and ash weight determination.

1. Chlorophyll concentration is determined by either spectrophotometry or fluorometry. The latter method is used on types of samples for which a low chlorophyll concentration is expected, e.g., Seston.

a. Spectrophotometric procedures

Excess water is removed from the sample using 52 µm netting. The chlorophyll is extracted with 90% acetone; extraction is carried out for 24 h in the dark at 4° C. The extract is centrifuged to reduce turbidity. Absorbance is read on a Beckman DB-G grating spectrophotometer at 750, 664, 480, and 430 nm. To allow partitioning of chlorophyll _a_ and phaeophytin _a_, HCl is added to the cuvette and absorbance reread at 664 and 750 nm. Equations for calculation of clorophyll _a_ and phaeophytin _a_ are given in Lorenzen (1967). Pigment ratios are defined by Margalef (1960) and by Watson and Osborne (1979).

b. Fluorometric procedures

Samples to be analyzed by fluorometry are stored on pre-ashed and tared glass fiber filters. Extraction and centrifugation are done in the manner described above for spectrophotometry samples. Preparation of the Turner model III fluorometer and equations for chlorophyll _a_ and phaeophytin _a_ calculation are described by Lorenzen (1966).

2. Dry weight and ash weight

The samples are dried at 60° C to constant weight to determine dry weight. They are then ashed at

550^{o} C for 3 h or until combustion is complete, and weighed to obtain ash weight. Replicate (N = 2 or 3) filters for determination of total suspended sediment concentration are gravimetrically analyzed with a Cahn Electrobalance (sensitivity = 10^{-5}g). A Mettler analytical balance (10^{-4}g) is used for all other samples except those >150 g, which are weighed with a top-loading Mettler (10^{-2}g).

B. Qualitative analysis

Carbon, hydrogen, and nitrogen content is determined using the Carlo Erba elemental analyzer. The sample is dried at 60^{o} C and ground to a fine powder. The instrument burns the sample, producing gases which are separated by a gas chromatographic column. Procedures for analyses and calculations are outlined in the Carlo Erba instruction manual.

III. Calculations

The data are typed into computer files directly from the data sheets. Calculations are performed by programs written in BASIC.

Inorganic Sediments

Fine (0.05 - 100 mm) sediments were sampled using a diaphragm (Guzzler) suction pump and either a collar or the intake nozzle of known cross-sectional area. Five cores each were taken at random from both erosional and depositional areas. The pump was operated until all of the fine material was removed from the sample area. The sample was placed in a large container and elutriated to separate the organic and inorganic materials. Volumes of each type of material were measured with an Imhoff cone.

Periphyton

Algae were collected from five separate rocks at each station using a device modified by C.E. Cushing (personal comm.) from that described by Stockner and Armstrong (1971) which sampled an area of 4.5 cm^2. The samples were passed through a 5.5 cm Whatman GF/C glass filter, folded, and wrapped in aluminum foil to exclude light. Each packet was then placed in a Whirl-pac bag, labelled, and frozen until analysis. The procedures for the evaluation of chlorophyll are given in Table 6.

RESULTS

For ease of presentation this section is divided into two main parts. The first deals with physical and biological conditions immediately after the fire (October-November 1979) and again approximately a year later (July-August 1980) and concentrates on the storage and benthic organism components (Table 5). The Fall 1979 data were collected before any major disturbances to the burned watersheds other than fire occurred. The Summer 1980 collections followed spring runoff and an intense rainstorm which was localized at the head of the East Fork of Little Loon Creek. The rainstorm, which happened early in July, affected only the East Fork and mouth of Little Loon Creek sites. Thus, by comparison of the data from these two sites with those from Char, W. Fk. Little Loon, and Little Creeks, it is possible to separate the effect of "controlled" (snowmelt) runoff from that of a severe spate. The second part of this section examines the transport of nutrients, organic matter, and inorganic sediments from burned and unburned watersheds. Treated here are the fall and summer water quality and transport samples (Table 5) as well as four sets of collections starting before spring runoff and extending over the main part of the run-off hydrograph (Fig. 2).

Conditions Immediately After the Fire and Following Spring Run-off

Storage

Information on the condition of and changes in materials deposited

on the stream bottom was obtained from two main sources: (1) core samples containing fine inorganic sediments (silt, sand, gravel) and deposited organic matter and (2) measurements of a random sample of larger inorganic sediments (pebbles, cobbles, boulders) coupled with estimates of their embeddedness (number buried and to what extent). In addition, estimates of the chlorophyll concentration of the sediments and of the composition of the coarse organic matter fraction of each stream was made from qualitative samples collected with a dip net.

Data on standing crops of fine inorganic and organic materials (Table 7) are given in their original form (ml/20 cm^2) but can be converted to g/m^2 through multiplication by 1325 and 150, respectively (based on densities of 2.65 and 0.3). As might be expected, the depositional areas generally held higher concentrations of material than did the erosional areas. However, there were several cases where the differences were negligible or the condition reversed; they included one burn (W. Fk. Little Loon) and two control tributaries (Indian, Marble) and three mainstream sites (MF at Indian, Pine, and Loon) during at least one season. Generally, organic matter was higher in all streams in fall than in summer. In the control streams, this was due to natural variations in the amount of leaf litter. But in the burn tributaries, the fall peak was due to accumulations of charcoal (e.g., E. and W. Fk. Little Loon) or fire-killed needles (e.g., Little Loon mouth) (Table 8) which by summer had been flushed from the streams. Thus, one could expect the seasonal pattern to hold in the future for the control and mainstream stations but (because of no source of new materials) for values to remain low throughout the year in the burn tributaries.

Mean habitat ($\overline{D} + \overline{E}$) relative and absolute amounts of organic

Table 7. Mean and standard error (in parenthesis) of benthic core standing crops (ml/20 cm^2) for the Mortar Creek Fire study. C = control stream, B = Burn stream, F = Fall 1979, S = Summer 1980, D = depositional, E = Erosional, D+E = combined habitats.

Site	Season	Habitat	N	Total Organic	Total Inorganic	Total	% Organic	% Inorganic
Teapot (C)	S	D	5	87.0 (48.8)	31.6 (17.5)	118.6 (64.9)	65.3 (12.7)	34.7 (12.7)
	S	E	5	21.0 (5.1)	50.5 (5.8)	71.5 (4.9)	29.4 (7.0)	70.6 (7.0)
	S	D+E	10	54.0 (25.6)	41.0 (9.2)	95.0 (31.7)	47.4 (9.1)	52.6 (9.1)
Char (B)	S	D	5	34.0 (12.6)	441.0(169.3)	475.0(180.8)	7.0 (1.2)	93.0 (1.2)
	S	E	5	4.6 (2.6)	83.2 (24.8)	87.8 (25.8)	6.4 (2.6)	93.6 (2.6)
	S	D+E	10	19.3 (7.8)	262.1(100.3)	281.4(107.6)	6.7 (1.3)	93.3 (1.3)
Pungo (C)	F	D	3	42.2 (31.8)	72.5 (28.5)	114.7 (60.2)	25.2 (12.3)	74.8 (12.3)
	F	E	3	1.3 (0.8)	12.2 (7.5)	13.5 (7.1)	17.4 (8.6)	82.6 (8.6)
	F	D+E	6	21.8 (16.9)	42.3 (18.9)	64.1 (35.3)	21.3 (6.9)	78.7 (6.9)
	S	D	5	30.0 (6.1)	396.2 (91.4)	426.2 (95.7)	7.8 (1.7)	92.2 (1.7)
	S	E	5	7.4 (3.3)	56.5 (36.3)	63.9 (39.4)	24.1 (11.1)	75.9 (11.1)
	S	D+E	10	18.7 (5.0)	226.4 (73.2)	245.0 (77.6)	16.0 (5.9)	84.0 (5.9)
Little (B)	F	D	2	40.2 (10.8)	26.8 (23.2)	67.1 (12.4)	65.2 (28.0)	34.8 (28.0)
	F	E	2	22.4 (4.6)	3.0 (1.6)	25.4 (6.2)	90.0 (3.8)	11.0 (3.8)
	F	D+E	4	31.3 (7.0)	15.0 (11.7)	46.3 (13.3)	77.0 (13.4)	23.0 (13.4)
	S	D	5	157.0 (22.6)	579.4(171.1)	736.4(164.5)	26.5 (7.4)	73.5 (7.4)
	S	E	5	27.0 (6.6)	316.0 (82.0)	343.0 (83.4)	8.9 (2.5)	91.1 (2.5)
	S	D+E	10	92.0 (24.3)	447.7 (99.6)	539.7(108.9)	17.7 (4.7)	82.3 (4.7)

Table 7 , continued.

Site	Season	Habitat	N	Total Organic	Total Inorganic	Total	% Organic	% Inorganic
Marble (C)	S	D	5	3.6 (1.8)	475.6 (72.0)	479.2 (72.3)	0.8 (0.3)	99.2 (0.3)
	S	E	5	5.2 (5.0)	583.2(132.5)	588.4(133.7)	0.7 (0.7)	99.3 (0.7)
	S	D+E	10	4.4 (2.5)	529.4 (73.3)	533.8 (73.9)	0.7 (0.4)	99.3 (0.4)
Little Loon (B)	F	D	3	8.3 (3.3)	117.8 (47.6)	126.2 (50.3)	8.3 (3.0)	91.7 (3.0)
	F	E	3	1.3 (0.6)	4.0 (1.6)	5.3 (1.5)	27.7 (10.4)	72.3 (10.4)
	F	D+E	6	4.8 (2.2)	60.9 (33.2)	65.7 (35.2)	18.0 (6.5)	82.0 (6.5)
	S	D	6	5.2 (2.2)	2310.0(444.7)	2316.0(444.9)	0.3 (0.2)	99.7 (0.2)
	S	E	4	2.8 (2.4)	785.0(196.2)	787.8(198.1)	0.3 (0.2)	99.7 (0.2)
	S	D+E	10	4.2 (1.6)	1700.5(364.9)	1704.7(365.4)	0.3 (0.1)	99.7 (0.1)
Loon (C)	S	D	5	8.0 (8.0)	1671.8(501.4)	1679.8(508.4)	0.2 (0.2)	99.8 (0.2)
	S	E	5	0.0	912.2(207.2)	912.2(207.2)	0.0	100.0 (0.0)
	S	D+E	10	4.0 (4.0)	1292.0(285.3)	1296.0(288.7)	0.1 (0.1)	99.9 (0.1)
MF Dagger (C)	F	D	3	1.9 (1.5)	4.8 (2.2)	6.77 (3.6)	25.7 (11.8)	74.3 (11.8)
	S	D	5	3.6 (0.7)	161.0 (42.0)	164.6 (42.4)	2.5 (0.61)	97.5 (0.6)
	S	E	5	3.0 (2.0)	96.5 (43.8)	99.5 (45.6)	1.4 (1.0)	98.6 (1.0)
	S	D+E	10	3.3 (1.0)	128.8 (30.6)	132.0 (31.3)	2.0 (0.6)	98.0 (0.6)
MF Indian (B)	F	D	3	31.0 (22.9)	4.5 (0.8)	33.5 (23.7)	65.0 (21.7)	35.0 (21.7)
	F	E	4	4.2 (3.0)	106.6 (35.6)	110.9 (33.6)	10.6 (9.8)	89.4 (9.8)
	F	D+E	7	15.7 (10.3)	62.9 (28.1)	78.6 (25.2)	33.9 (14.7)	66.1 (14.7)
	S	D	5	4.8 (1.5)	321.7 (38.2)	326.5 (38.0)	1.5 (0.5)	98.5 (0.3)
	S	E	5	0.16 (0.1)	28.7 (11.1)	28.8 (11.2)	0.9 (0.7)	99.1 (0.7)
	S	D+E	10	2.5 (1.1)	175.2 (52.3)	177.7 (53.0)	1.2 (0.4)	98.8 (0.4)
MF Pine (B)	F	D	3	8.3 (6.0)	433.3(133.3)	441.7(139.2)	1.5 (0.8)	98.5 (0.8)
	F	E	3	3.3 (3.3)	453.3(186.2)	456.7(183.2)	2.8 (2.8)	97.2 (2.8)
	F	D+E	6	5.8 (3.3)	443.3(102.5)	449.2(102.9)	2.1 (1.3)	97.9 (1.3)
	S	D	5	6.0 (2.9)	2091.0(863.2)	2097.0(862.1)	0.5 (0.2)	99.5 (0.2)
	S	E	4	0.1 (0.1)	1013.5(327.2)	1013.5(327.2)	0.1 (0.1)	100.0 (0.1)
	S	D+E	9	3.4 (1.8)	1612.1(510.5)	1615.5(510.4)	0.3 (0.2)	99.7 (0.2)

Table 7, continued.

Site	Season	Habitat	N	Total Organic	Total Inorganic	Total	% Organic	% Inorganic
White (C)	F	D	3	166.7 (72.6)	366.7(166.7)	533.3(116.7)	36.5 (15.7)	63.5 (15.7)
	F	E	3	8.3 (3.5)	61.7 (32.5)	70.0 (36.0)	13.2 (1.3)	86.8 (1.3)
	F	D+E	6	87.5 (48.1)	214.2(102.1)	301.7(117.1)	24.9 (8.8)	75.1 (8.8)
	S	D	5	5.1 (2.2)	907.6(297.4)	912.7(296.9)	1.1 (0.5)	98.9 (0.5)
	S	E	5	10.1 (5.2)	524.0(203.7)	534.1(208.6)	1.8 (0.5)	98.2 (0.5)
	S	D+E	10	7.6 (2.8)	715.8(181.6)	723.4(182.3)	1.4 (0.4)	98.6 (0.4)
W. Fk. Little Loon (B)	F	D	4	247.5(172.8)	252.3(102.8)	500.0(256.0)	34.2 (11.2)	65.9 (11.2)
	F	E	4	10.0 (4.6)	70.8 (32.8)	80.8 (37.2)	13.4 (6.1)	86.6 (6.1)
	F	D+E	8	128.8 (91.8)	161.6 (60.6)	290.4(143.6)	23.8 (7.1)	76.2 (7.1)
	S	D	5	8.3 (4.6)	424.2 (98.6)	432.5(100.6)	2.1 (1.0)	97.9 (2.0)
	S	E	5	18.2 (6.3)	382.8 (89.3)	401.0 (91.6)	6.7 (2.6)	93.3 (2.6)
	S	D+E	10	13.2 (4.0)	403.5 (63.1)	416.8 (64.3)	4.4 (1.5)	95.6 (1.5)
Indian (C)	F	D	6	28.0 (14.1)	29.4 (13.4)	57.4 (13.0)	47.6 (15.9)	52.4 (15.9)
	S	D	5	13.0 (1.2)	160.6 (43.0)	173.6 (43.5)	8.8 (1.5)	91.2 (1.5)
	S	E	5	11.0 (2.9)	564.4(150.2)	575.4(151.8)	2.9 (1.4)	97.1 (1.4)
	S	D+E	10	12.0 (1.5)	362.5 (99.8)	374.5(100.1)	5.8 (1.4)	94.2 (1.4)
E. Fk. Little Loon (B)	F	D	4	25.0 (14.9)	1081.2(373.2)	1106.2(386.7)	1.6 (0.8)	98.4 (0.8)
	F	E	5	1.0 (0.3)	53.2 (14.0	54.2 (14.1)	3.1 (1.6)	96.9 (1.6)
	F	D+E	9	11.7 (7.4)	510.1(236.4)	521.8(243.2)	2.4 (0.9)	97.6 (0.9)
	S	D	5	1.2 (1.0)	1817.0(757.3)	1818.2(756.9)	0.1 (0.1)	99.9 (0.1)
	S	E	5	5.4 (4.9)	1442.6(224.4)	1448.0(223.0)	0.5 (0.4)	99.5 (0.4)
	S	D+E	10	3.3 (2.4)	1629.8(377.5)	1633.1(377.0)	0.3 (0.2)	99.7 (0.2)

Table 7, continued.

Site	Season	Habitat	N	Total Organic	Total Inorganic	Total	% Organic	% Inorganic
MF Loon (B)	S	D	5	13.6 (5.2)	734.1(313.5)	747.7(312.5)	2.6 (1.0)	97.0 (1.0)
	S	E	5	4.1 (2.4)	1196.8(260.0)	1200.9(259.9)	0.4 (0.3)	99.6 (0.3)
	S	D+E	10	8.8 (3.1)	965.4(206.9)	974.3(206.0)	1.5 (0.6)	98.5 (0.6)
MF Mouth (B)	S	D	5	11.2 (9.7)	1513.4(419.6)	1524.6(421.0)	0.7 (0.6)	99.3 (0.6)
	S	E	5	33.0 (18.3)	1217.0(511.4)	1250.0(502.8)	4.9 (2.6)	95.1 (2.6)
	S	D+E	10	22.1 (10.4)	1365.2(315.7)	1387.3(312.5)	2.8 (1.4)	97.2 (1.4)

Table 8 . Coarse organic matter composition (%) of qualitative samples as determined by visual examination.

Site	Season	Moss	Decid. Leaves	Conif. Needles	Sticks	Bark	Amorphous Detritus	Charcoal
Teapot (C)	S	20	30	10			20	
Char (B)	S	5			40	20	35	
Pungo (C)	F	7	65	40		5	3	
	S	5	30		30	30		
Little (B)	F	5		10	4		1	80
	S	15		70	10	5		
White (C)	F		47	47	6			
	S		30	30	5	15	20	
W. Fk. Little Loon (B)	F			5				95
	S				40	50	10	
Indian (C)	F		40	40		10		
	S	30	15		40		15	
E. Fk. Little Loon (B)	F		5	20		2	8	65
	S				30	30		
Marble (C)	F		45	45	3		2	
	S			60	30		10	
Little Loon (B)	F		35	70			5	
	S		15		7	70	3	
Loon (C)	F		40	50		5	5	
	S		20	10	60		10	
MF Dagger (C)	F	10		30	45		10	
	S	10			50	30	10	
MF Above Indian (B)	F	5	10	60				
	S	10	30	10		30	20	
MF At Pine (B)	F		10	50	40	20	5	
	S					5	95	
MF At Mouth (B)	S					90	5	

matter in the burn tributaries compared to their controls differed between stream pairs (Table 7). In Char Creek in the summer, the organic content (both relative and absolute) was much less than in Teapot Creek, suggesting a negative impact of the fire. In Pungo Creek before the fire, the percent and absolute values were higher than in Little Creek but decreased in relative importance (though increasing in absolute amounts) to levels about equal to those in Little Creek following snowmelt. E. Fk. Little Loon had a percent organic matter composition much less than that of its control in both seasons although in absolute terms it was markedly less only in summer. Relative and absolute organic matter composition for the W. Fk. and mouth of Little Loon were similar to controls for all instances for which comparisons are available. Absolute amounts of organic matter in the mainstream generally were lower than in the tributaries whether the latter were unburned or not. In only two cases did the percent organic matter for the mainstream sites exceed 20%, a relatively common occurrence for the tributaries.

For the mainstream in the fall, organic matter values were high in the upper reaches but decreased below Indian Creek. In the summer, values were uniformly low at all stations. In both cases, the pattern is in keeping with that expected along large river systems in general (Vannote et al. 1980). However, the values for Middle Fork at Pine in summer are considerably lower than for the other mainstream sites and may reflect the input of inorganic sediments from Little Loon Creek.

In all cases, except the summer fines at Char Creek, the concentration of chlorophyll was markedly less in the burn tributaries than in their controls (Table 9). In the mainstream, Dagger supported

Table 9. Chlorophyll concentration of benthic sediments for the Mortar Creek Fire study sites. (C = control stream, B = burn stream)

STATION	mg Chlorophyll/g AFDW			
	FALL		SUMMER	
	Fine	Coarse	Fine	Coarse
Teapot (C)	NS	NS	0.031	0.551
Char (B)	NS	NS	0.069	0.089
Pungo (C)	0.191	0.353	0.127	0.083
Little (B)	0.062	0.062	0.040	0.051
White (C)	0.188	0.093	0.091	0.280
WF Little Loon (B)	0.142	0.004	0.037	0.028
Indian (C)	1.135	0.308	0.214	0.157
EF Little Loon (B)	0.004	0.029	0.000	0.087
Marble (C)	0.642	0.174	0.102	0.017
Little Loon (B)	0.340	0.254	0.019	0.101
Loon (C)	0.567	0.042	0.189	0.156
MF-Dagger (C)	1.300	0.064	0.285	0.032
MF-Above Indian (B)	0.310	0.061	0.280	0.252
MF-At Pine Flat (B)	0.208	0.023	0.027	0.003
MF-Above Loon (B)	NS	NS	0.073	0.023
MF-At Mouth (B)	NS	NS	0.070	0.011

higher concentrations of chlorophyll in the fine fraction than did the other stations. Although, in summer, Indian had levels comparable to Dagger in the fine component and the highest value of all in the coarse fraction.

Relative amounts of fine inorganic sediments are the reverse of those described for organic matter. Inorganic matter values were higher in the summer than in the fall for all tributaries (both burn and control) for which comparisons are possible. In the control and several of the burn tributaries, mean habitat values never exceeded 716 ml/20 cm^2 but at East Fork and mouth of Little Loon Creek values increased 3 and 30 fold between fall and summer to reach levels of 1630 and 1700 ml/20 cm^2, respectively. Similar high values were seen on the mainstream only at Pine and the mouth. From these data and on-site observations we conclude that inorganic sediment movement and deposition were significant only at three burn sites (E. Fk. and mouth Little Loon, MF at Pine). Serious adverse changes in fine sediment composition were seen only in tributaries of link magnitude 100 or larger in heavily burned watersheds and were caused or accelerated by severe rainstorms.

Mean dimensions of the coarse inorganic sediments are given in Table 10. Length, width, and height correspond to the a, b, and c axes, respectively. Volume is a useful way of considering these values simultaneously. There were no major differences in mean volumes at a site between fall and summer. However, mean substrate volumes of the burn tributaries were appreciably less than for their respective controls at Char, Little, and E. Fk. Little Loon. On the mainstream, substrate volumes at Dagger and the mouth were considerably greater than at the other sites. Median width (D_{50}) values always were less in the

Table 10. Summary of coarse inorganic substratum and embeddedness measurements (mean and standard error) for each station of the Mortar Creek Fire study. C = control stream, B = burn stream, N = number of rocks measured, PCSIEM = percent of cases in which sand was included as the embedding material.

SITE	SEASON	DIMENSIONS (cm & dm^3)						N	EMBEDDEDNESS		
		$\bar{X}$ Length	$\bar{X}$ Width	$\bar{X}$ Height	$\bar{X}$ Volume	$\bar{X}$ Mean Dim.	Median Width (D_{50})		% Embedded	% Embeddedness	PCSIEM
Teapot (C)	S	22(1.7)	14(1.1)	10(1.0)	11.3(3.6)	15(1.2)	10	100	72	48(2.6)	9
Char (B)	S	12(1.1)	8(0.9)	4(0.3)	2.0)1.2)	8(0.7)	6	100	37	45(3.8)	18
Pungo (C)	F	22(2.5)	15(1.6)	8(0.9)	9.9(2.7)	15(1.6)	10	64	31	24(3.7	
	S	31(2.7)	20(1.7)	13(1.1)	26.8(5.0)	21(1.8)	14	100	50	38(2.2)	1
Little (B)	F	12(0.7)	8(0.5)	5(0.4)	0.7(0.1)	8(0.5)	8	35	69	48(5.3)	14
	S	11(0.9)	8(0.6)	4(0.3)	1.1(0.3)	7(0.6)	5	100	54	38(3.5)	27
White (C)	F	14(0.8)	10(0.6)	6(0.3)	1.3(0.3)	10(0.6)	10	50	52	35(5.0)	18
	S	20(2.0)	13(1.3)	7(0.6)	8.1(2.1)	13(1.3)	9	100	51	44(3.9)	48
W. Fk. Little Loon (B)	F	13(0.7)	10(0.6)	6(0.4)	1.1(0.2)	9(0.5)	8	50	58	34(4.0	
	S	17(1.1)	10(0.6)	6(0.4)	2.1(0.4)	11(0.7)	10	100	52	46(3.4)	28
Indian (C)	F	21(0.9)	16(0.7)	9(0.4)	4.1(0.5)	15(0.6)	14	100	82	16(1.4)	
	S	26(1.3)	18(1.0)	8(0.4)	6.6(1.1)	17(0.9)	15	100	33	33(4.9)	19
E. Fk. Little Loon (B)	F	15(0.9)	11(0.7)	6(0.4)	1.4(0.3)	10(0.6)	9	50	50	24(3.5)	
	S	12(1.0)	8(0.6)	4(0.3)	1.2(0.4)	7(0.6)	6	100	33	54(4.4)	22
Marble (C)	S	21(1.3)	14(0.7)	7(0.4)	4.4(0.9)	14(0.8)	12	100	65	31(2.0)	26
Little Loon (B)	F	14(1.0)	10(0.7)	6(0.4)	1.3(0.3)	10(0.7)	9	50	70	33(4.1)	
	S	18(1.7)	12(1.2)	7(0.7)	7.2(1.9)	12(1.2)	7	100	33	41(4.1)	28
Loon (C)	S	18(1.7)	13(1.3)	7(0.6)	6.8(1.6)	12(1.2)	8	100	33	30(2.8)	27
MF Dagger (C)	S	36(2.7)	23(1.8)	16(1.3)	25.6(5.7)	25(1.8)	20	52	44	21(3.7)	17
MF Above Indian (B)	F	30(2.2)	20(0.9)	11(0.5)	8.9(1.0)	20(0.9)	19	100	58	25(3.9)	
	S	29(1.6)	20(1.0)	11(0.6)	11.3(2.2)	19(1.0)	17	100	50	19(2.3)	25
MF At Pine Flat (B)	F	21(0.9)	15(0.6)	9(0.4)	4.2(0.7)	15(0.6)	14	99	79	41(2.9)	38
	S	26(2.4)	18(1.5)	9(0.8)	9.2(3.1)	18(1.5)	18	50	78	58(6.1)	38
MF Above Loon	S	24(1.3)	16(1.0)	9(0.5)	6.5(1.1)	16(0.9)	12	100	44	30(2.9)	24
MF At Mouth (B)	S	41(5.2)	29(3.3)	14(1.4)	50.9(24.7)	28(3.1)	22	50	40	16(2.8)	19

burn streams than in their controls except for the W. Fk. Little Loon. In addition, they showed a further decrease between fall and summer whereas the mean volumes of the controls commonly increased. D_{50} values for the mainstream sites generally were quite similar to each other except possibly at Pine in fall and Loon in summer. The percent of rocks that were embedded ranged between 30 and 82% with no consistent pattern between burn and control. However, the value always decreased in the burn tributaries between fall and summer. The extent (%) to which the rocks were buried also varied widely between sites but generally increased between the two sampling periods. Except for W. Fk. Little Loon, the percent of the cases in which sand was included as the embedding material always was higher in the burn streams than in their controls.

In almost all cases, the b-axis cumulative frequency curves of the burned tributaries were displaced to the right of their respective controls (Figs. 4, 5). The exception was the curves for E. Fk. Little Loon and White Creeks which clustered together. A shift of the curves to the right indicates an increase in the abundance of the smaller particle sizes. There were no appreciable differences in particle size frequency for the mainstream sites.

These results indicate that the coarse inorganic substrate composition and embeddedness were altered in most of the burn tributaries. However, there was no detectable effect on the mainstream or on the W. Fk. Little Loon Creek.

Benthic Macroinvertebrates and Associated Detritus

Insects and other bottom-dwelling invertebrates were identified

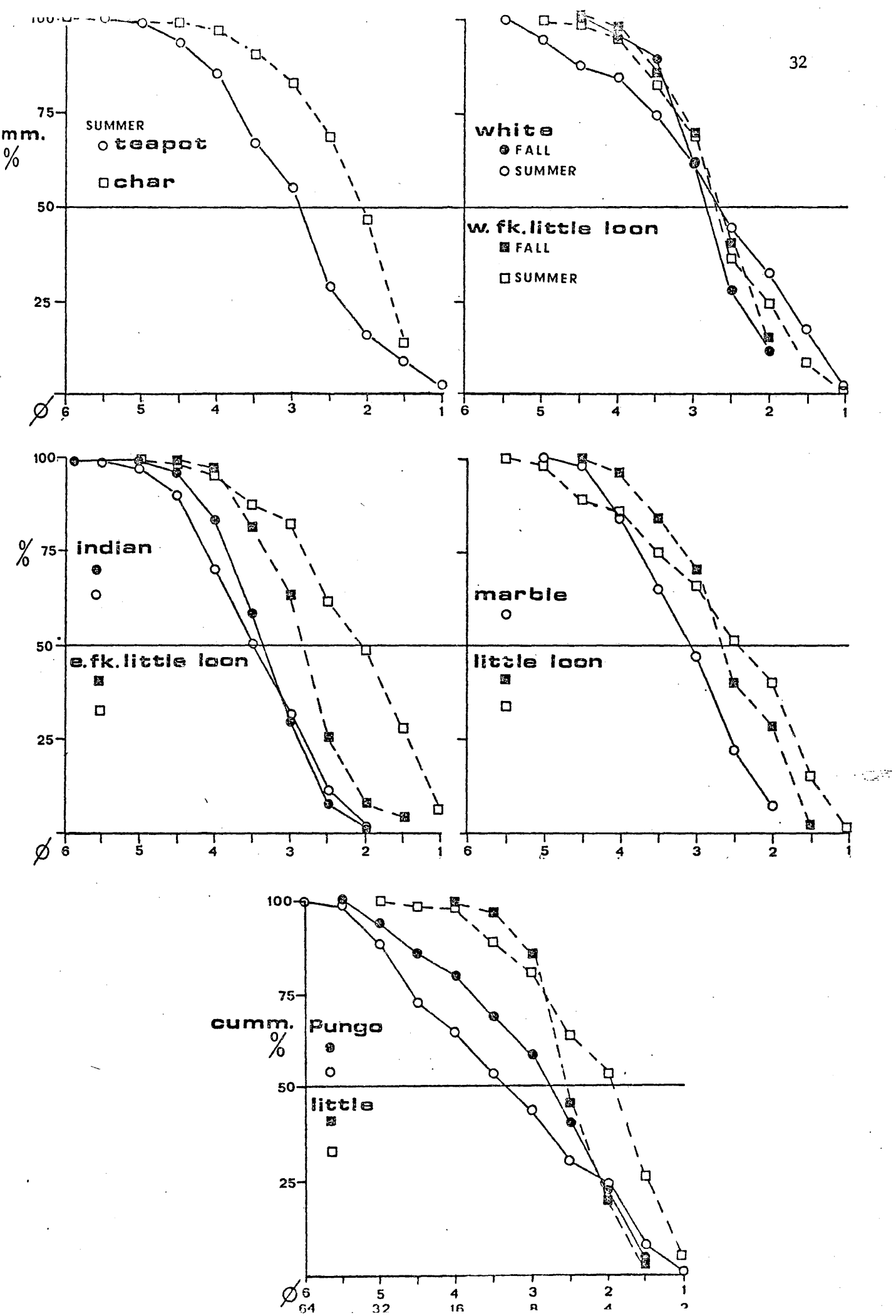
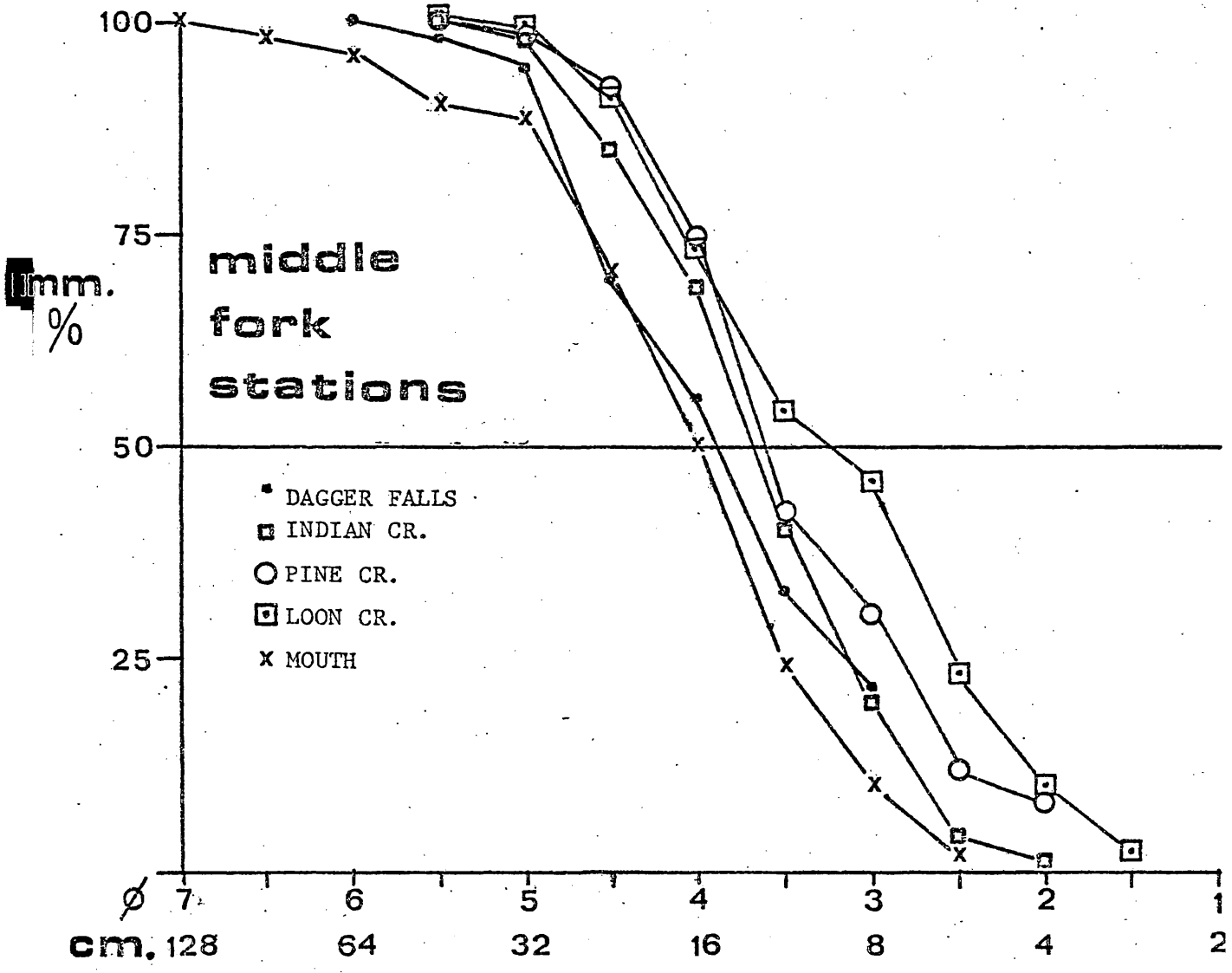

cumm. %
SUMMER
teapot
char
white
FALL
SUMMER
w. fk. little loon
FALL
SUMMER
indian
e. fk. little loon
marble
little loon
cumm. %
Pungo
little
100
75
50
25
Ø
6
5
4
3
2
1
64
32
16
8
4
2

Figure 5. Cumulative frequency curves of substrate particle sizes in the Middle Fork of the Salmon River, Summer 1980.


100
75
50
25
mm.
%
middle
fork
stations
DAGGER FALLS
INDIAN CR.
PINE CR.
LOON CR.
MOUTH
ø 7 6 5 4 3 2 1
cm. 128 64 32 16 8 4 2

to the lowest practicable taxon, counted, and weighed. The data were examined from several perspectives including taxonomic and trophic composition. In addition, biological indices of community structure and condition were calculated.

The burn study sites and their respective controls generally were quite similar with respect to the kinds of organisms they supported (Table 11). A total of 81 taxa were identified. In general, the tributary streams supported about half and the mainstream sites about one third that number. The low numbers of taxa in Teapot Creek and the two lowermost Middle Fork sites probably are due to the fact that they were sampled only once. Thus, from this data the only burn sites which appear to have been severely altered in regards to species composition are the East Fork and mouth of Little Loon Creek. Only 14 taxa were collected from the East Fork site compared to 30 for its control. Although the total number of taxa at the mouth of Little Loon Creek (38) was comparable to that found at Marble Creek (43), 22 of them were found only in the Fall (vs. 8 for Marble Creek). The latter is one indication of the impact that the July spate had on the Little Loon Creek fauna.

Total numbers in each of the major taxonomic groups (Table 12) showed no consistent pattern between stations or seasons and therefore the data are difficult to interpret. There is the suggestion that all of the streams except Char were not adversely affected directly by the fire but did decline markedly following runoff from the burned watersheds. Because of its small size, Char Creek may have been much more severely affected by the heat of the fire than were the other (larger) sites. For example, visual examination showed that much of the moss

STREAM	EMPHEMEROPTERA																		COLEOPTERA						
	Ameletus cooki	A. oregonensis	A. similor	A. velox	Baetis bicaudatus	B. tricaudatus	Cinygmula sp.	Ephemerella doddsi	E. flavilinea	E. grandis	E. lystrix	E. inermis	E. spinifara	Epeorus deceptivus	E. grandis	E. longimanus	Paraleptophlebia heteronea	Rhithrogena hageni	Dubiraphia sp.	ELMIDAE - A	ELMIDAE - B	Narpus sp.	Optioservus sp.	Zaitzevia sp.	PSEPHENIDAE
Teapot Cr. C			1		1		1																		
Char Cr. B		1			+	1	-		1		1	-		-		1	+	-							
Pungo Cr. C				-	+	+	+	+	1		+	-	-	1			+	-	1	1			+		
Little Cr. B			1	+	+	1	+		1		-	+		-	1	-	+	+					+		
White Cr. C		-			+	+	+	-	1			-					+	-	1	-	-	-	+		
WF Little Loon B	1			1	+	1	+		1		+	+	+	1		+	+	-				-	1		
Indian Cr. C					+	1	-	+	1	-	1	+	-	1		1	-	+							
EF Little Loon B					1			1																	
Marble Cr. C				1	+	+	+		1	-	+	+		1			+	-	1			-	+	-	1
Little Loon Cr. B		-			+	1	+	-	1		-	-	-	-		1	+	+				-	+		
Loon Cr. C					1	+	-	-	1		1	+	-	1		1		+					-		
MF Dagger Falls C					+	1	-	-			+	+	-	1	-		-	+							
MF Above Indian Cr. B					+	+			1		1	+	-	1		1	-	-					-		
MF At Pine Flat B		-			1	+	-					-	-	1		1	-		-				-		
MF Above Loon B				1	1	1						1		1				1				-	-		
MF Mouth B					1	1									1			1					1		

- = Oct. 79
1 = July 80
+ = Both

STREAM	PLECOPTERA																		MISC.								
	Calineuria sp.	Claassenis sabulosa	CAPNIIDAE	CHLOROPERLIDAE	Hesperoperla pacifica	Isogenoides sp.	Isoperla sp.	Megarcys sp.	Nemoura sp.	Paraleuctra sp.	Perlesta placida	Pteronarcys californica	Nemoura sp.	Setvena bradleyi	Skwala sp.	Visoka cataractae	Yoraperla brevis	Zapada oregonensis	Ammicola sp.	Hydracarina	Lumbriculus sp.	Lymnaea sp.	NEMATODA	TUBIFICIDAE	Physa sp.	Pisidium sp.	TURBELLARIA
Teapot Cr. C			1			1								1			1	1			1			1			1
Char Cr. B				+			-			-				+			+	+						+			+
Pungo Cr. C			+	+		1		-	-	+			-	1		+	-	+						+			+
Little Cr. B	-		1	+					-	+			-	+		-	+	+		-	-			+			+
White Cr. C		+		+		1	1		-	+			-	1				+						+			1
WF Little Loon B	-	+		+		+			-	+			-	1			+	+					1	+			+
Indian Cr. C				-		1		-										-									
EF Little Loon B																				1				1			
Marble Cr. C		+	1	+	+	+				-								+		+			-	+	+		-
Little Loon Cr. B		+		+	-	+				+				-				-						+			-
Loon Cr. C		1		-	1							-			-												
MF Dagger Falls C		-		-	+							-			-												
MF Above Indian Cr. B				-	1						-	-														-	
MF At Pine Flat B		1		-		-						-							+			+		-	+		
MF Above Loon B		1			1																1						
MF Mouth B		1																	1			1					

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TRICHOPTERA

STREAM	Arctopsyche grandis	Brachycentrus sp.	Ceraclea sp.	Cheumatopsyche sp.	Glossosoma sp.	Hydropsyche sp.	Hydroptilla sp.	Lepidostoma sp.	Limnephilus sp.	LIMNEPHILIDAE	Micrasema sp.	Molanna sp.	Neophylax sp.	Neothremma sp.	Parapsyche elsis	Rhyacophila acropodes	R. anagelita	R. hyalinata	R. vaccua	R. verrula	R. vepulsa
Teapot Cr. C																1					1
Char Cr. B	-												1	-		+			1	1	+
Pungo Cr. C	-														1	+				1	+
Little Cr. B	-				-			-						-	1	+			1		+
White Cr. C	-	-				-									1	+			1		+
WF Little Loon B	-			-	1	-			-	1				-	1	+					+
Indian Cr. C	-	+		1	+						-			-	1	+					+
EF Little Loon B																			1		1
Marble Cr. C	1	+			-	+	1	+	1								1				1
Little Loon Cr. B	-	-		-	-	-		-							-	+			1		-
Loon Cr. C	+	+				-			-												1
MF Dagger Falls C	+	+	-			-								-			-	-			+
MF Above Indian Cr. B	+	+												-							1
MF At Pine Flat B		+		+	-	-			+			+									
MF Above Loon B	1	1																			1
MF Mouth B	1	1																			

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DIPTERA

	Antocha sp.	*Atherix variagata*	CERATOPOGONIDAE	CHIRONOMIDAE	*Hexatoma* sp.	*Philorus* sp.	*Simulium* sp.	*Tipula* sp.	Total Represented (81 possible)
Teapot Cr. C				1			1		15
Char Cr. B				+			1	-	29
Pungo Cr. C				+			1	+	36
Little Cr. B			1	+			+	+	40
White Cr. C	-			+			1	-	36
WF Little Loon B			+	+			-	1	41
Indian Cr. C	+			+			-	-	30
EF Little Loon B									14
Marble Cr. C	+	+	1	+	+			+	43
Little Loon Cr. B		-		-	-			-	38
Loon Cr. C	+			+		1		+	26
MF Dagger Falls C	+	+		+		-		-	30
MF Above Indian Cr. B	+	1		+				-	24
MF At Pine Flat B	-	-		1				1	30
MF Above Loon Cr. B				1					13
MF Mouth B	1			1		1	1		14

- = Oct. 79
1 = July 80
+ = Both

Table 12. Relative abundance (%) and number of taxa (in parentheses) comprising the principal orders and total numbers/m^2 of macroinvertebrates collected from control (C) and burn (B) sites during this study.

STATION	EPHEMEROPTERA		PLECOPTERA		TRICHOPTERA		COLEOPTERA		DIPTERA		MISC.		Total no/m^2	
	Oct '79	July '80	Oct '79	July '80	Oct '79	July '80	Oct '79	July '80	Oct '79	July '80	Oct '79	July '80	Oct '79	July '80
Teapot (C)	NS	32 (3)	NS	27 (6)	NS	3 (2)	NS	0 (0)	NS	6 (2)	NS	32 (3)	NS	761
Char (B)	14 (7)	4 (6)	70 (6)	18 (4)	11 (4)	2 (6)	0 (0)	0 (0)	1 (2)	67 (2)	4 (2)	9 (2)	825	3538
Pungo (C)	38(10)	28 (8)	20 (8)	15 (7)	12 (3)	7 (4)	12 (1)	5 (3)	4 (3)	27 (4)	14 (2)	18 (2)	1036	2473
Little (B)	35 (9)	13(10)	28 (7)	16 (7)	16 (6)	3 (4)	1 (1)	1 (1)	7 (3)	33 (4)	14 (4)	34 (2)	2077	1112
White (C)	26 (8)	20 (5)	15 (5)	17 (7)	18 (5)	9 (4)	35 (4)	20 (2)	4 (4)	7 (2)	2 (1)	27 (2)	673	1484
W Fk Little Loon (B)	42 (8)	29(12)	7 (8)	12 (7)	9 (7)	5 (6)	1 (1)	3 (1)	31 (3)	28 (3)	5 (2)	23 (3)	3681	1146
Indian (C)	16 (8)	34 (9)	1 (2)	1 (1)	55 (8)	53 (6)	0 (0)	0 (0)	7 (6)	40 (8)	5 (5)	8 (3)	913	524
E Fk Little Loon (B)	NS	2 (2)	NS	0 (0)	NS	2 (2)	NS	0 (0)	NS	82 (2)	NS	14 (2)	NS	192
Marble (C)	12 (8)	10 (9)	5 (6)	4 (5)	70 (5)	36 (5)	1 (3)	2 (3)	7 (6)	40 (8)	5 (5)	8 (3)	2836	877
Little Loon (B)	47(10)	5 (7)	11 (8)	2 (4)	9 (9)	1 (2)	1 (2)	1 (1)	23 (8)	90 (2)	9 (2)	1 (1)	1714	360
Loon (C)	20 (6)	54 (8)	4 (3)	2 (2)	40 (5)	19 (4)	1 (1)	0 (0)	35 (3)	25 (4)	0 (0)	0 (0)	961	937
MF Dagger Falls (C)	37 (9)	26 (6)	3 (5)	1 (1)	40 (9)	9 (3)	2 (1)	0 (0)	17 (5)	61 (3)	1 (1)	3 (1)	677	475
MF Above Indian (B)	20 (6)	35 (7)	2 (3)	1 (1)	59 (5)	20 (3)	3 (1)	0 (0)	15 (3)	44 (3)	1 (1)	0 (0)	913	552
MF At Pine Flat (B)	4 (6)	23 (5)	1 (3)	2 (1)	90 (7)	13 (4)	2 (3)	0 (0)	1 (2)	3 (2)	2 (4)	59 (3)	2396	509
MF Above Loon (B)	NS	49 (7)	NS	3 (2)	NS	38 (3)	NS	0 (0)	NS	8 (1)	NS	2 (1)	NS	252
MF At Mouth (B)	NS	34 (4)	NS	4 (1)	NS	27 (3)	NS	0 (0)	NS	14 (4)	NS	21 (2)	NS	288

in the stream had been damaged or killed by the fire; this effect was not evident at the other burn sites. All of the burn streams showed large reductions in the relative abundance of Ephemeroptera following runoff. Trichoptera appear to have decreased in abundance as a result of the fire (except at Char!) and to have remained low through July 1980. Since the numbers of Diptera were affected the least, that group showed apparent increases in relative abundance whenever Ephemeroptera or Trichoptera declined.

The effects of fire on the benthic invertebrates were not expected to be seen primarily along taxonomic lines. Instead it was postulated that if any change occurred it would be in the trophic organization of the community based on fire-induced differences in food resources. In order to examine the trophic responses of the consumers in the burn and control streams, the various invertebrate taxa were placed in functional feeding groups according to criteria first proposed by Cummins (1973). Data for both numbers and biomass were examined.

In terms of abundance, the algal-feeding grazers generally constituted between 5 and 30% of the community at any site (Table 13). Shredders, which feed on large particles of allochthonous detritus, were much less abundant than the grazers. They made up less than 15% of the total numbers at a site and were absent in a number of cases particularly in the main stream in July. In contrast, the fine particulate organic matter gatherers were omnipresent and commonly accounted for 10 to 30% of any community. Filter feeders, which utilize fine organic matter carried in suspension, made up less than 10% of the invertebrate communities in the smaller tributaries but in the main river and larger tributaries commonly exceeded 20%. Miners

Table 13. Absolute and relative abundance of macroinvertebrate functional groups (C = control, B = burn stream).

STREAM	GRAZERS				SHREDDERS				GATHERERS				FILTER FEEDERS				MINERS				PREDATORS				OTHERS			
	Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80	
	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%	$\bar{X}/m^2$	%
Teapot (C)	NS	NS	136	18	NS	NS	61	8	NS	NS	247	32	NS	NS	18	2	NS	NS	88	12	NS	NS	211	28	NS	NS	0	0
Char (B)	41	5	43	1	121	15	281	8	448	52	415	11	4	1	42	1	13	3	2415	68	131	16	342	10	67	8	0	0
Pungo (C)	17	2	282	11	71	7	143	6	429	40	500	15	2	<1	8	<1	168	16	853	34	226	22	560	23	123	12	127	5
Little (B)	7	<1	46	4	202	10	122	11	1007	28	125	11	130	6	37	3	167	8	451	41	319	15	326	29	255	12	5	<1
White (C)	77	12	109	7	11	2	7	<1	120	16	189	12	32	5	31	2	33	5	425	29	166	25	429	29	234	35	294	20
W Fk Little Loon (B)	1332	36	268	23	43	1	44	4	584	14	64	6	222	6	17	1	1049	28	450	39	245	7	270	24	206	6	33	3
Indian (C)	20	2	150	29	18	2	0	0	169	19	57	10	421	46	249	48	194	21	50	10	64	7	18	3	27	3	0	0
E.Fk Little Loon (B)	NS	NS	4	2	NS	NS	0	0	NS	NS	4	2	NS	NS	4	2	NS	NS	174	91	NS	NS	6	3	NS	NS	0	0
Marble (C)	122	4	54	6	1430	50	290	33	327	12	66	8	597	21	8	1	181	6	339	39	157	6	73	8	22	1	47	5
Little Loon (B)	522	30	11	3	30	2	2	<1	719	45	9	3	51	3	0	0	196	11	325	90	136	8	11	3	15	1	2	<1
Loon (C)	5	<1	389	42	122	13	6	<1	317	31	132	16	295	31	162	17	188	20	218	23	24	3	30	3	10	1	0	0
MF Dagger Falls (C)	59	9	105	22	9	1	0	0	312	46	74	16	236	35	33	7	7	1	205	43	35	5	58	12	19	3	0	0
MF Above Indian (B)	46	5	120	22	44	5	0	0	178	18	77	14	584	64	106	19	13	2	164	30	15	2	85	15	33	4	0	0
MF At Pine Flat (B)	42	2	417	82	129	5	24	5	164	7	41	8	1995	83	5	1	0	0	10	2	17	<1	12	2	49	2	0	0
MF Above Loon (B)	NS	NS	58	27	NS	NS	0	0	NS	NS	59	24	NS	NS	93	37	NS	NS	21	8	NS	NS	11	4	NS	NS	0	0
MF At Mouth (B)	NS	NS	129	45	NS	NS	0	0	NS	NS	63	21	NS	NS	65	23	NS	NS	20	7	NS	NS	11	4	NS	NS	0	0

are fine particle feeders such as worms (Oligochaeta) and midge larvae (Chironomidae), which burrow into sediments to feed. They were rare (<5%) in a number of cases, especially in Fall 1979 but in Summer 1980 they rose in relative importance and commonly constituted 20 to 90% of the invertebrates at a site. Predators accounted for 15 to 30% of the community in the smaller tributaries but became reduced in importance (1-15%) in the Middle Fork and larger tributaries.

Pronounced differences in numerical frequency of occurrence of functional feeding groups between control and burn tributary streams were seen for site pairs except for Little and Pungo Creeks (Table 13). Grazers were higher than the control stream in the West Fork and lower in the East Fork and at the mouth of Little Loon Creek and in Char Creek. Shredder numbers were lower in percent composition than the control at the mouth of Little Loon. Filter feeders were lower in relative abundance than in the control streams and miners were higher at both the East Fork and mouth locations. Miners also were lower in Char Creek than in the control. Except for miners, all of the differences indicated were present on both sampling dates (where such data are available) and therefore cannot be conclusively attributed to the fire. However, they generally are consistent with our predicted responses for conditions immediately following the fire (see original proposal). Increases in the miners occurred only in July and therefore probably are associated with the effects of runoff in the burned watersheds. The only Middle Fork station to show a difference was Pine Creek Flat in July 1980 where the abundance of filter feeders was drastically reduced over that found previously.

Examination of the data on invertebrate biomass (Table 14) indicates a

Table 14. Macroinvertebrate dry weights (mg/m^2) for the Mortar Creek Fire study sites. (C = control stream, B = burn stream)

STREAM	GRAZERS				SHREDDERS				GATHERERS				FILTER FEEDERS				MINERS				PREDATORS				OTHERS			
	Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80		Oct '79		July '80	
	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%	mg/m^2	%
Teapot (C)	NS		14	13	NS		40	39	NS		13	13	NS		21	20	NS		8	8	NS		7	7	NS		0	
Char (B)	4	1	45	5	107	34	221	22	112	35	76	8	1	<1	100	10	1	<1	404	42	80	25	147	15	12	4	0	
Pungo (C)	2	<1	19	10	51	12	8	4	206	50	83	44	1	<1	20	10	20	5	29	15	106	26	26	14	23	6	5	3
Little (B)	32	2	8	5	249	16	12	7	387	25	23	14	7	<1	7	4	254	16	73	46	267	17	36	22	372	24	3	2
White (C)	4	5	11	6	33	44	3	2	9	12	9	5	2	3	12	7	2	3	89	53	15	20	20	12	10	13	26	15
W Fk Little Loon (B)	136	35	62	9	5	1	16	2	42	11	110	16	8	2	318	46	83	22	107	15	16	4	60	9	96	25	19	3
Indian (C)	2	<1	28	14	2	<1	0		6	<1	15	7	571	95	145	74	8	1	2	1	18	2	7	4	0		0	
E Fk Little Loon (B)	NS		3	4	NS		0		NS		40	59	NS		1	2	NS		17	25	NS		7	10	NS		0	
Marble (C)	138	11	25	7	304	24	61	17	14	1	202	57	437	35	12	3	15	1	32	9	44	3	21	6	305	25	4	1
Little Loon (B)	24	<1	1	3	6	<1	1	3	388	14	3	16	249	8	0		17	<1	8	44	2230	76	5	29	7	<1	1	5
Loon (C)	<1	<1	29	4	31	<1	57	7	3447	93	116	14	219	6	552	68	13	<1	38	5	7	<1	16	2	2	<1	0	
MF-Dagger Falls (C)	28	9	11	8	30	10	0		17	6	4	3	209	71	10	8	<1	<1	9	7	7	2	95	74	7	2	0	
MF-Above Indian (B)	2	<1	19	4	115	3	0		796	21	20	4	2801	75	377	77	3	<1	22	5	6	<1	49	10	15	<1	0	
MF-At Pine Flat (B)	1741	13	1402	94	381	3	6	<1	861	6	55	4	10651	77	8	<1	89	<1	1	<1	21	<1	18	1	7	<1	0	
MF-Above Loon (B)	NS		30	31	NS		0		NS		10	11	NS		37	39	NS		8	8	NS		10	11	NS		0	
MF-At Mouth	NS		2433	95	NS		0		NS		27	1	NS		37	1	NS		11	<1	NS		50	2	NS		0	

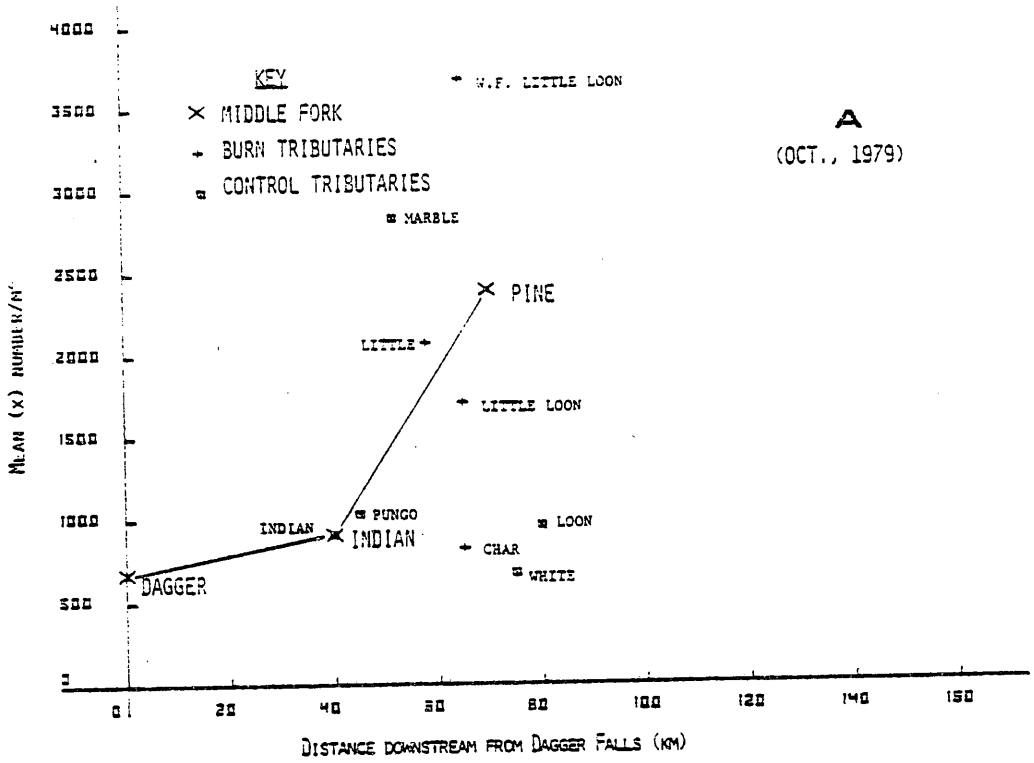
somewhat different partitioning among the various functional groups than was found for numbers but the overall impression concerning impact of the fire is much the same. Grazer biomass generally made up less than 15% of the community at a site but occasionally exceeded 30% (WF Little Loon in Fall; lower three Middle Fork stations in Summer). The shredders, as might be expected on the basis of current riverine ecosystem theory (Vannote et al. 1980), made up a substantial portion of the community (20-40%) in the first and second order tributaries but were rare or absent in the main river. Likewise, gatherers commonly accounted for 10 to 50% of the biomass in the tributaries but usually were only 6% or less in the Middle Fork. In Fall 1979, filter feeders constituted less than 10% of the community biomass in all tributaries except Indian and Marble but exceeded 70% at all of the Middle Fork sites sampled. The situation in the summer was more erratic; values were less than 20% in most cases but occasionally attained 40 to 80%. Miners usually accounted for only a few percent of the total by weight. Predators in half of the cases made up less than 10% of the community by weight and exceeded 30% on only two occasions.

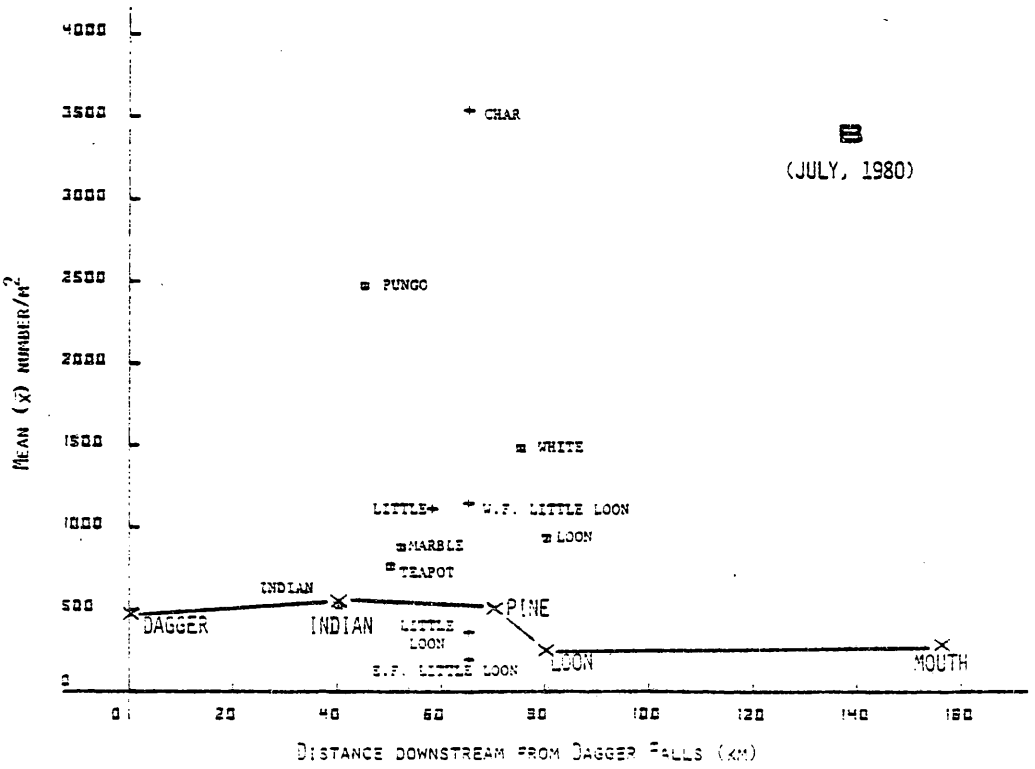
Examination of invertebrate biomass in the burn streams with respect to their controls indicates a variable response which seems to be associated mainly with the size of the stream and the impact of runoff. No trends were evident in the main river that could clearly be attributed to the fire but in the tributaries several different responses were seen. Relative biomass of functional feeding categories in Char Creek were reduced in all cases except for miners and predators. West Fork of Little Loon Creek contained substantially more grazers and miners and fewer shredders than White Creek in Fall 1979 but by Summer

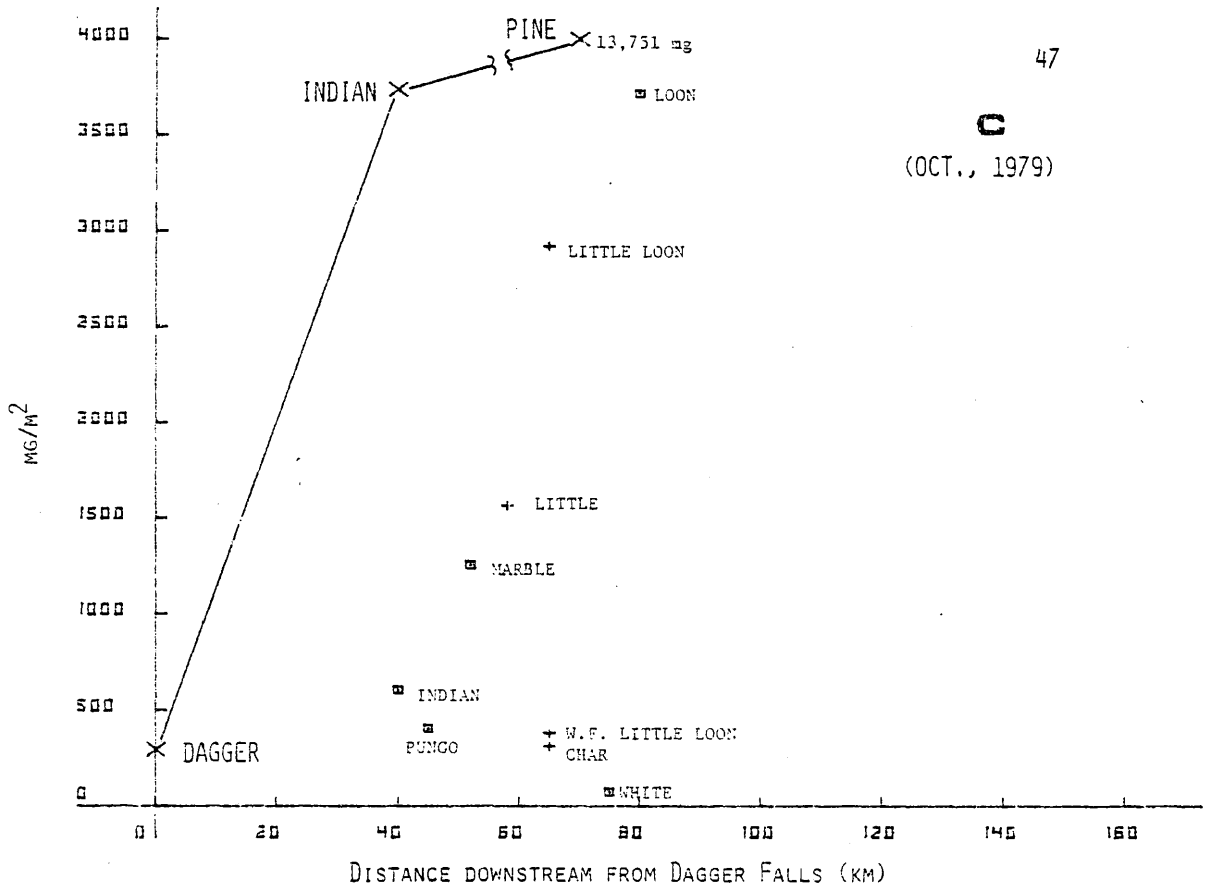
1980 these differences had evened out. In the summer collection, filter feeders accounted for a disproportionate amount in West Fork and was the only group that appeared to have been affected by the secondary effects of the fire. In contrast to conditions found in the West Fork of Little Loon, the East Fork supported markedly greater weights of miners and gatherers and less biomass of filter feeders than found in Indian Creek. The proportion of biomass in the different categories at the mouth of Little Loon Creek also differed from that of the other sites in its drainage when compared to its control. In this case, there was relatively less biomass in most functional groups when compared to the control. The most biologically significant difference was the increase in the proportion of miners in the summer; although the predators also were substantially higher at the burn site than in the control in both streams. Relative biomass composition in Little Creek was similar to or greater than that in Pungo Creek for most categories in Fall 1979 with the notable exception of gatherers and filter feeders. In Summer 1980, relative biomass in Little Creek was less than the control in all categories except miners and predators.

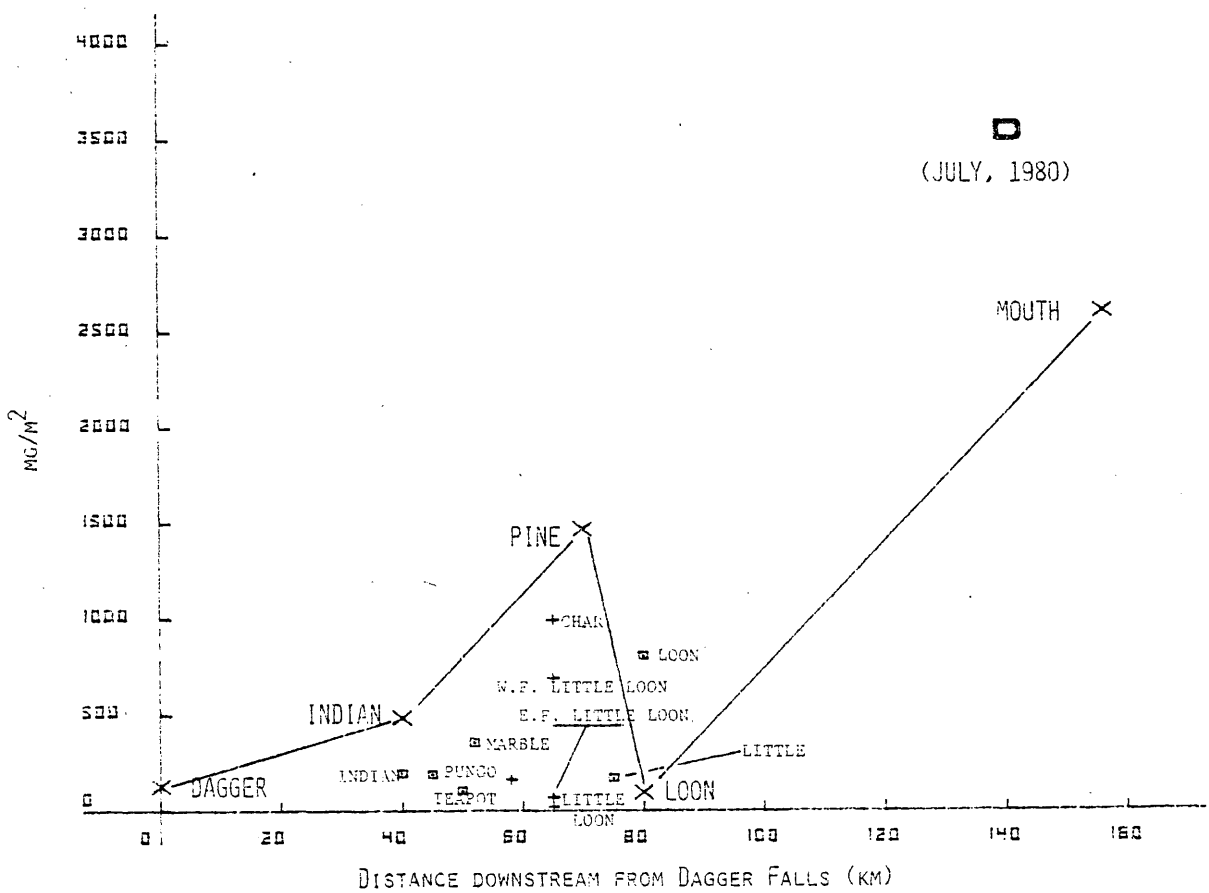
Total numbers and biomass of benthic macroinvertebrates, calculated from the data in Tables 13 and 14 for each season, are plotted in Figure 6. In Fall 1979, abundance in the main river increased downstream largely as a result of greater numbers of Brachycentrus. In Summer 1980, values remained uniformly low over the entire length. Numerical values for the tributaries in the fall were quite variable between sites. White Creek (a control site) supported the lowest numbers and West Fork of Little Loon (a burn site) the highest. Only in Char Creek did total numbers show possible adverse effects due to fire.

Figure 6. Density (A, B) and biomass (C, D) of benthic invertebrates at the tributary and mainstream sites of the Mortar Creek Fire study soon after the fire (Oct.) and following runoff (July).


KEY
MIDDLE FORK
BURN TRIBUTARIES
CONTROL TRIBUTARIES
A
(OCT., 1979)
W.F. LITTLE LOON
MARBLE
PINE
LITTLE
LITTLE LOON
PUNGO
LOON
INDIAN
INDIAN
CHAR
DAGGER
WHITE
MEAN (x) NUMBER/M²
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
150
DISTANCE DOWNSTREAM FROM DAGGER FALLS (KM)


B
(JULY, 1980)
CHAR
PUNGO
WHITE
LITTLE
W.F. LITTLE LOON
LOON
MARBLE
TRAPOT
INDIAN
DAGGER
INDIAN
PINE
LITTLE LOON
W.F. LITTLE LOON
LOON
MOUTH
MEAN (x) NUMBER/M²
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
DISTANCE DOWNSTREAM FROM DAGGER FALLS (KM)


C
(OCT., 1979)
PINE
13,751 mg
INDIAN
LOON
LITTLE LOON
LITTLE
MARBLE
INDIAN
PUNGO
W.F. LITTLE LOON
CHAR
DAGGER
WHITE
MG/M2
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
DISTANCE DOWNSTREAM FROM DAGGER FALLS (KM)


D
(JULY, 1980)
MOUTH
PINE
CHAR
LOON
W.F. LITTLE LOON
INDIAN
E.F. LITTLE LOON
MARBLE
LITTLE
INDIAN
PUNGO
DAGGER
TEAPOT
LITTLE LOON
LOON
MG/M2
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
DISTANCE DOWNSTREAM FROM DAGGER FALLS (KM)

In summer, total numbers for Little and West Fork of Little Loon Creeks were intermediate to those of the controls indicating little or no effect from the fire aftermath. But the East Fork and mouth of Little Loon supported considerably fewer individuals than the control tributaries, indicating an adverse effect, and total numbers at Char Creek were considerably higher, suggesting a possible enhancement effect. Total biomass values yield an interpretation similar to that for total numbers although the specifics differ. In particular, where numbers were low or intermediate in the main river compared to the tributaries, biomass generally was higher in the main river than in the tributaries. Also both Char Creek and West Fork of Little Loon had some of the lowest values found in the tributaries in the autumn. In the summer, there was less of a spread in values between the tributaries than seen with numbers. But the two Little Loon sites again came out the lowest and Char Creek the highest. In addition, there is the possibility that the biomass of Little Creek was reduced over what might be expected.

Shannon-Weiner (Peet 1974) and Biotic Condition (Winget and Mangum 1979) Indices were calculated for the benthic macroinvertebrate data from 1979 and 1980 (Table 15). The Biotic Condition Index proved to be insensitive to the effects of fire and its aftermath. Even the severe physical changes in Little Loon Creek were not reflected by this index.

The Shannon-Weiner (H') values suggest that the fire had no direct impact on community heterogeneity. (Values for burned and control tributaries for the Fall samples were similar). In addition, there was little effect on the benthic invertebrate fauna due to runoff (e.g., see Char, W. Fk. Little Loon and Little Crs.) except for

Table 15. Shannon-Weiner (H') and Biotic Condition (BCI) Indices and species richness for the benthic macroinvertebrates for each station of the Mortar Creek Fire study (C = control, B = burn stream).

	H'		BCI		Richness	
Stream	Oct '79	July '80	Oct '79	July '80	Oct '79	July '80
Teapot (C)	NS	2.16	NS	97	NS	16
Char (B)	1.96	1.30	142	116	21	20
Bungo (C)	2.74	2.59	134	106	27	28
Little (B)	2.58	2.38	121	108	30	28
White (C)	2.73	2.34	118	108	27	21
S Fk Little Loon (B)	2.11	2.45	101	106	29	32
Indian (C)	2.37	2.09	154	135	22	18
S Fk Little Loon (B)	NS	.82	NS	73	NS	8
Marble (C)	1.95	2.33	107	94	33	37
Little Loon (B)	2.69	.60	124	113	39	17
Loon (C)	2.35	2.36	111	147	18	18
NF Dagger Falls (C)	2.68	2.04	145	118	30	14
NF Above Indian (B)	1.84	2.74	109	134	25	13
NF At Pine Flat (B)	0.92	1.77	84	77	NS	14
NF Above Loon (B)	NS	2.05	NS	118	NS	14
NF At Mouth (B)	NS	2.37	NS	93	NS	14

those sites where heavy erosion and sediment transport occurred (E. Fk. and mouth of Little Loon Cr.). In the latter case, dramatic decreases in H' took place and reached levels commonly associated with several polluted streams (Wilhm 1970). There was a suggestion of a downstream decrease in H' values along the mainstream in Fall 1979. But this did not hold for Summer 1980 samples which were comparable to values from before the fire (Summer 1978, Minshall et al. unpubl.; range from 1.13 at Dagger to 2.59 at the mouth). A consistently low set of H' values was obtained for MF at Pine Creek Flat which could be due to the influence of Little Loon Creek. Although this possibility cannot be discounted, it is unlikely since the lowest value occurred in the Fall before any major impact was seen at the other burn sites. Also, the low H' value was due to a disproportionate number of Brachycentrus, a filter-feeder which especially could be expected to be affected adversely by the effects of a fire.

The trends indicated by H' are supported by the data for species richness (Table 15). Burn sites sustained numbers of taxa similar to those of the control sites except at East Fork and mouth of Little Loon Creek in July 1980. This again suggests that the main adverse effects on community structure came as a result of severe runoff, erosion, and sediment transport from burned watersheds. Most of the losses in numbers of taxa occurred among the Trichoptera and Diptera.

Values for organic matter collected along with the invertebrates complement those reported in the storage subsection. Levels in the tributaries ranged from 2 to over 90 g AFDW/m^2 but generally were higher than in the mainstream (Table 16). Values usually remained the same or decreased from fall to summer. A notable exception was the

Table 16. Organic detritus (g AFDW/m^2) associated with the benthic macroinvertebrate samples for each station of the Mortar Creek Fire study (C = control, B = burn stream).

	Oct. 1979		July 1980	
	Organic Detritus	% Charcoal	Organic Detritus	% Charcoal
Teapot (C)	NS		20.9	6
Char (B)	91.1	78	92.2	100
Pungo (C)	21.9	0	13.9	0
Little (B)	70.6	78	32.5	82
White (C)	47.8	0	15.1	0
WF Little Loon (B)	76.3	58	59.7	58
Indian (C)	4.3	0	59.3	0
EF Little Loon (B)	NS		16.1	10
Marble (C)	9.2	0	6.9	0
Little Loon (B)	28.8	0	21.5	0
Loon (C)	2.1	0	16.1	0
MF-Dagger (C)	3.4	0	3.9	0
MF-Above Indian (B)	3.2	0	4.2	0
MF-At Pine Flat (B)	13.1	0	36.6	5
MF-Above Loon (B)	NS		8.8	0
MF-At Mouth (B)	NS		1.9	0

Middle Fork at Pine which had much higher concentrations than the other mainstream sites and showed a doubling in levels from fall to summer. In addition, the Pine station contained a small amount of charcoal which probably was flushed out of Little Loon Creek. The burn tributaries always contained more material than their control stream, except for the East Fork of Little Loon in summer. The latter is further evidence that considerable amount of organic matter was exported from Little Loon Creek as a result of the July rainstorm.

Periphyton

Chlorophyll a and biomass values for the periphyton (= attached algae and moss) growing on natural rock substrates showed similar trends (Table 17). There was no clear effect of the fire in the Autumn 1979 samples. Two of the burn tributary streams (Little Cr. and W. Fk. Little Loon) had lower values than their respective control streams but two others (E. Fk. and mouth of Little Loon) had higher values. The reasons for these differences are not apparent from the available data. However, in the Summer 1980 samples values for the burned streams were lower than the controls at three sites (Char, E. Fk. and mouth L. Loon) and these can be attributed to flushing and scouring of the streambed. Periphyton standing crops for other burn sites which were not subjected to scouring (Little Cr., W. Fk. L. Loon Cr.) did not differ appreciably from their control streams. Before the fire, both Teapot and Char Creeks supported thick mats of aquatic moss. In Autumn 1979, the mats at Char Creek remained intact but were badly scorched. By Summer 1980 most of the moss at Char Creek had been flushed away while that at Teapot Creek was unchanged. The difference

Table 17. Chlorophyll a (mg/m^2) and biomass (g AFDW/m^2) standing crops of periphyton for each station of the Mortar Creek Fire study (C = control, B = burn stream).

STREAM	CHLOROPHYLL				BIOMASS			
	Oct. 79		July 80		Oct. 79		July 80	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Teapot (C)	NS	NS	33.58	15.27	NS	NS	18.55	8.90
Char (B)	NS	NS	2.92	2.30	NS	NS	1.71	2.30
Pungo (C)	45.17	23.96	3.98	3.15	19.61	9.93	3.62	3.20
Little (B)	20.57	8.50	3.84	4.55	8.19	5.18	5.31	3.55
White (C)	12.85	2.44	3.57	1.34	15.95	4.57	1.64	0.70
WF Little Loon (B)	55.14	24.76	2.07	1.08	18.65	9.15	4.58	1.51
Indian (C)	12.58	5.17	9.56	5.49	11.37	7.12	6.17	3.42
EF Little Loon (B)	9.37	5.62	0.38	0.25	7.97	5.59	1.08	0.59
Marble (C)	4.98	2.78	6.63	4.26	3.60	1.79	14.02	5.46
Little Loon (B)	11.38	14.56	1.15	1.48	7.99	7.88	1.81	0.64
Loon (C)	47.84	19.77	11.38	8.54	20.53	3.18	5.21	2.60
MF-Dagger (C)	5.03	5.96	42.06	36.54	10.80	9.37	27.88	19.97
MF-Above Indian (B)	12.73	9.01	7.94	7.93	10.55	4.79	9.74	8.77
MF-At Pine Flat (B)	36.36	9.61	22.19	14.05	21.73	8.17	25.69	8.82
MF-Above Loon (B)	NS	NS	4.20	2.54	NS	NS	8.43	2.57
MF-At Mouth (B)	NS	NS	2.83	2.13	NS	NS	4.65	3.91

between the East and West Forks of Little Loon Creek in the Summer 1980 is particularly striking and instructive since both are burn streams located in close proximity to one another. Periphyton levels in the West Fork were comparable to those in the control stream even though White Creek was shaded by riparian vegetation. Levels in East Fork were much less than in its control stream or in the West Fork. Both Little Loon streams lacked riparian vegetation but the periphyton of the East Fork had been scored away by the July cloudburst and sediment torrent which left the West Fork untouched.

Autotrophic Potential

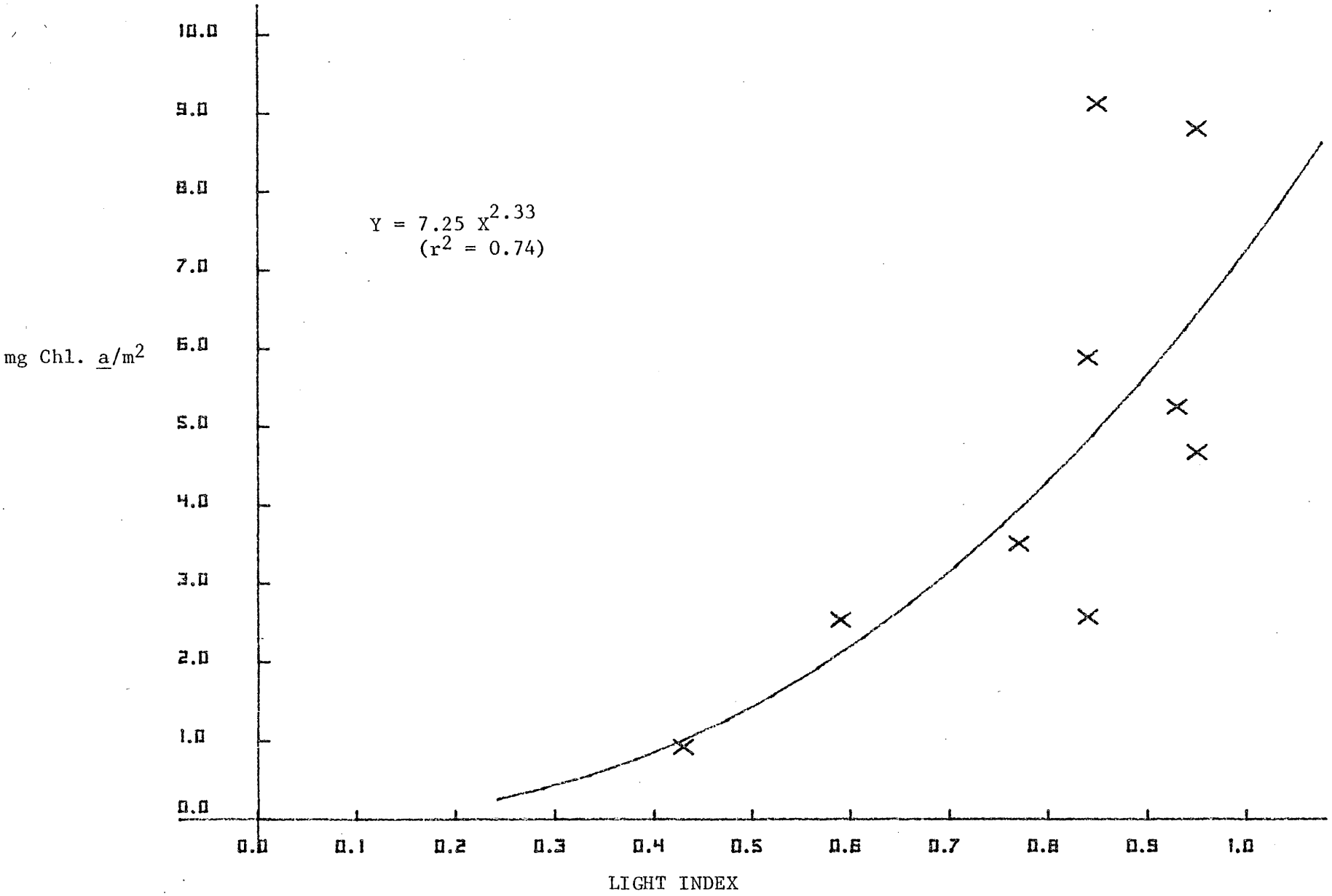
The ability of algae to colonize and grow on previously bare substrate over a known time interval was used to assess the autotrophic potential of the study streams. This measurement involved the placement of unglazed tiles in the streams early in the growing season, their retrieval near the end of July, and their evaluation for accumulation of chlorophyll and biomass (Table 18). These values differ from those of the previous subsection in that the period of growth on the tiles is known. Because the tiles were placed in the streams during high discharge, several sets were washed away including those in the East Fork and mouth of Little Loon Creek. However, rocks substituted for the tiles give an indication of conditions at the mouth of Little Loon Creek.

There was an exponential relationship between the amount of chlorophyll and the light index (Fig. 7). The light index is a ratio comparing values from clear tubes filled with hydroxyethyl cellulose with those of completely darkened tubes (= dark ÷ light). From the relationship shown

Table 18. Autotrophic potential as indicated by tiles placed in the study streams and allowed to colonize for 36 to 44 days between June 14 and July 30. Values are the means of at least six individual tile measurements. Most of the missing values are due to the tiles being washed away by high water. At Little Loon mouth and Loon Creeks, rocks were substituted for the missing tiles. Water chemistry values are means of the June and July samples.

Site	N	Chl. a (mg/m^2)	AFDW (g/m^2)	Chl/Biomass (mg/g)	Velocity (cm/s)	Depth (cm)	Light Index	Canopy (% Closed)	Alkal. mg/l	NO_3 µg/l	Ortho-P µg/l
Teapot (C)	7	0.9266	0.9523	1.516	48	8	0.43	100	38.5	154	143
Char (B)	11	9.1303	7.9951	1.157	154	14	0.85	5	40.8	268	246
Pungo (C)	7	8.8184	5.9236	1.533	23	7	0.95	60	45.0	<10	151
Little (B)	10	5.2678	4.2454	1.224	48	7	0.93	30	59.5	23	144
White (C)	9	5.8925	2.7791	2.352	31	3	0.84	90	74.5	31	205
WF Little Loon (B)	10	4.6874	5.1759	0.959	103	6	0.95	10	48.2	38	157
Indian (C)	7	2.5457	2.7238	1.110			0.59	5	34.9	<10	112
EF Little Loon (B)	NS	NS	NS	NS	NS	NS	NS	10	50.9	58	309
Marble (C)	NS	NS	NS	NS	NS	NS	NS	10	24.5	<10	172
Little Loon (B)	4	0.7310	1.2502	0.452	70	20	NS	40	48.8	22	272
Loon (C)	4	4.8653	4.9639	1.267	55	12	NS	10	39.8	<10	179
MF Dagger (C)	6	2.5898	4.6668	0.964	13	12	0.84	0	27.6	<10	110
MF Above Indian (B)	6	3.5141	7.2398	0.689	10	16	0.77	0	31.5	<10	233
MF At Pine Flat (B)	NS	NS	NS	NS	NS	NS	NS	0	30.1	<10	148
MF Above Loon (B)	NS	NS	NS	NS	NS	NS	NS	0	32.8	<10	137
MF At Mouth (B)	NS	NS	NS	NS	NS	NS	NS	0	29.6	<10	140

Figure 7. Relationship between chlorophyll content and light as determined from data obtained during the Mortar Creek Fire study, Summer 1980.


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
mg Chl. a/m2
Y = 7.25 X2.33
(r2 = 0.74)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
LIGHT INDEX

in the figure, one would expect that wherever the fire appreciably reduced the riparian cover an increase in the autotrophic potential would occur. In general this was the case (Table 18) and is best seen for Char Creek where the reduction in the degree of shading by the fire was most pronounced. Although interpretation is hampered by the lack of control values, it appears that the autotrophic potential at the mouth of Little Loon Creek (and probably in the East Fork as well) was reduced below that which could reasonably be expected. This agrees with findings reported in the Periphyton subsection which suggest that the algae at the East Fork and mouth sites were severely affected by scouring.

Transport of Nutrients, Inorganic Sediments, and Organic Matter from Burned and Unburned Watersheds

Wildfire has the potential to disrupt nutrient cycles within forested watersheds. The intense heat from such fires results in the removal of vegetation, the combustion of soils, and the mineralization of nutrients. Because of the destabilization of the ground cover and the burning out of roots, increased susceptibility to erosion occurs. Runoff in burned watersheds thus has the potential to transport abnormally large amounts of nutrients (ash), and both organic (charcoal), and inorganic particles into recipient streams. In addition to these direct inputs to fire-impacted streams, burned watersheds may be expected to carry higher loads of dissolved nutrients due to disruption of the normal biologically-controlled nutrient cycles. Streams in burn areas also are subject to higher flows due to reduced evapotranspiration as well as flashier flow due to the absence of the dispersing ability of the former plants and litter. However the actual impact to a stream is the result of many interacting variables such as the intensity of the burn, the type and depth of soil, gradient, amount and pattern of precipitation, etc. which determine the extent and degree of the adverse effect. One of the purposes of this study was to examine the effects of wildfire on water quality in different sized streams in the Salmon River Basin. In order to accomplish this, samples of dissolved nutrients, organic particles, and inorganic solids were collected and analyzed on six occasions beginning shortly after the fire and encompassing

the major hydrographic events associated with runoff (Fig. 2).

Investigators have utilized a variety of approaches in an effort to determine the effects of fire. In some cases prescribed burns have been set in experimental drainages (e.g. Lewis 1974, Tiedemann et al. 1978, Debano and Conrad 1978) and in one instance, a natural fire burned several drainages for which extensive pre-fire baseline data were available (Schindler et al. 1980). But in most situations the researchers have had to rely on a posteriori comparisons between sites within and adjacent to the burn with the sites located on different sections of the same stream (Johnson and Needham 1964, Lotspeich 1972) or in different drainages (McColl and Grigal 1975, Hoffman and Ferreira 1976, Albin 1979). In the present study it was necessary to employ the latter technique because of the extensiveness of the burn and the fact that the fire did not occur in previously instrumented drainages or where the chemical characteristics of the stream were already well known. Consequently, our basic strategy was to characterize the range of concentrations and stream loads of the principal water quality constituents over the widest possible range of flow and temperature regimes in an array of burned and nearby, unburned watersheds. However, it must be appreciated that there are a number of problems inherent in this approach which are compounded when the study sites are not readily accessible. Most importantly there are intrinsic differences between streams which cannot be fully compensated for. In addition, when the sites cannot be visited frequently or monitored continuously events may be missed (such as a thunderstorm or a temperature-induced change in discharge) which

have major bearing on interpretation of the data.

Concentration of Materials in the Water

Concentrations (µg or mg/l) of chemical constituents, sediments, and particulate organic matter being carried by each of the streams during the study period are shown in Table 19. Overall ionic content of the water is indicated by specific conductance (Fig. 8). A distinct seasonal pattern can be seen with minimum values coinciding with the period of high discharge and maximum values occurring during base flow. Except for White Creek, the burn tributaries (small or medium) generally had higher specific conductances than the control streams just after the fire and during spring runoff. At Char Creek and West Fork of Little Loon the differences tended to disappear during base flow. In the mainstream total ion concentrations were virtually the same at all sites.

Alkalinity measures a prominent component of total dissolved solids (carbonates). Like specific conductance it showed an indirect relation with discharge indicating a dilution effect during periods of increased runoff. Concentrations of the burn and small control tributaries overlapped but Little Loon was notably higher than the medium sized controls. Concentrations of calcium, magnesium, and sodium behaved similar to those of alkalinity. Only calcium, the dominant cation, is plotted (Fig. 8). Both White and Little Creeks showed very high calcium levels at base flow as did the East Fork and mouth of Little Loon. Little Loon Creek is known to flow through outcroppings of quartzite which has a high relative mobility for calcium (Miller 1961). Streams adjacent to Little Loon with quartzite

Table 19. Results of chemistry and nutrient sampling program, Mortar Creek Fire study.

Site	Date Month Year	Time	Discharge (m^3/s)	Specific Conductance (µ mhos)	Alkalinity as $CaCO_3$ (mg/l)	Orthophosphate-P† (µg/l)	Nitrate - N (µg/l)	Sulfate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Dissolved Organic Carbon (mg/l)*	Suspended Sediment (mg/l)	Particulate Organic Matter (mg/l)	Seston Percent Organic
MF DAGGER	171079	2130	7.2110	---	---	---	200	---	10.1	0.5	3.2	0.17	1.07	1.2	0.30	44
MF DAGGER	140680	1360	---	51.5	28.1	115	< 10	< 6.0	2.3	0.2	0.2	0.11	2.22	1.9	0.71	46
MF DAGGER	200780	2200	10.3720	60.0	27.2	105	< 10	---	7.1	0.3	1.3	0.13	1.10	0.5	0.26	65
MF INDIAN	261079	0950	20.9880	72.4	---	---	50	---	10.1	0.5	3.0	0.11	1.62	1.7	0.61	45
MF INDIAN	020380	1230	---	95.6	46.8	129	< 10	7.0	13.6	0.8	4.5	0.18	0.48	0.9	0.38	54
MF INDIAN	210480	1900	58.2320	76.3	34.1	98	110	< 6.0	9.3	0.6	1.4	0.22	2.48	17.2	5.60	34
MF INDIAN	220480	1000	62.0620	75.0	33.8	139	20	< 6.0	7.0	0.4	0.7	0.12	2.08	11.8	3.95	35
MF INDIAN	110580	1700	130.6020	52.8	23.4	109	< 10	< 6.0	5.2	0.2	0.4	0.10	3.03	6.4	2.21	37
MF INDIAN	160580	1630	105.7640	48.7	23.2	93	< 10	< 6.0	4.1	0.2	0.3	0.10	2.26	2.7	0.90	40
MF INDIAN	170580	1000	---	50.0	24.4	201	< 10	< 6.0	5.0	0.3	0.3	0.11	2.09	3.0	0.97	38
MF INDIAN	150680	1530	---	47.7	21.6	359	< 10	< 6.0	4.3	0.3	0.3	0.11	2.08	4.8	1.41	34
MF INDIAN	220780	1830	40.7700	73.0	34.0	104	< 10	---	8.9	0.4	1.5	0.13	1.01	1.3	0.57	53
MF INDIAN	230780	1525	---	77.6	40.5	107	< 10	---	8.9	0.4	1.6	0.13	1.23	1.4	0.57	49
MF INDIAN	240780	0720	---	74.9	34.6	91	< 10	---	9.0	0.4	1.6	0.12	0.87	1.6	0.70	53
INDIAN CK	271079	1540	1.7830	86.2	46.3	---	50	---	11.1	1.0	5.0	0.14	0.81	0.4	0.16	63
INDIAN CK	020380	1500	1.5080	117.0	47.0	158	< 10	8.5	13.2	1.1	8.6	0.28	0.91	1.0	0.25	42
INDIAN CK	220480	1500	21.8190	55.2	25.4	125	---	< 6.0	6.5	0.5	1.4	0.52	2.36	19.0	4.19	23
INDIAN CK	120580	1200	12.1370	54.6	25.2	92	< 10	6.8	5.7	0.3	0.4	0.11	2.04	4.4	1.33	35
INDIAN CK	160580	2040	---	---	---	132	< 10	< 6.0	4.6	0.3	0.3	0.11	1.70	2.8	1.24	48
INDIAN CK	170580	1115	9.7210	59.2	26.9	154	< 10	6.8	6.4	0.4	0.6	0.11	1.40	1.8	0.58	41
INDIAN CK	230780	1600	---	54.9	24.4	153	< 10	< 6.0	3.7	0.4	0.3	0.23	1.40	2.7	0.87	39
INDIAN CK	230780	1046	3.2740	77.4	34.0	97	< 10	---	8.5	0.5	2.0	0.24	0.72	1.2	0.39	48
INDIAN CK	230780	2052	---	80.2	35.1	112	< 10	---	8.7	0.5	2.0	0.21	0.64	1.0	0.34	49
INDIAN CK	240780	0724	---	77.2	34.6	112	< 10	---	8.7	0.5	2.1	0.21	0.63	1.0	0.38	51
EFK INDIAN	020380	1630	0.0960	91.8	41.4	155	20	< 6.0	11.1	1.2	1.9	0.29	1.02	0.5	0.15	54
EFK INDIAN	200480	1700	0.9350	45.9	19.4	132	30	< 6.0	5.2	0.4	1.0	1.04	2.25	38.8	9.25	24
EFK INDIAN	110580	1306	0.4780	48.5	23.1	121	< 10	< 6.0	4.1	0.3	0.4	0.12	1.54	3.6	0.84	31
EFK INDIAN	160580	2100	---	53.7	24.6	137	< 10	< 6.0	7.0	0.5	0.6	0.39	1.21	2.5	0.57	31
EFK INDIAN	170580	0830	0.3540	53.4	24.2	178	< 10	< 6.0	7.1	0.6	0.7	0.38	1.15	3.7	0.94	31
EFK INDIAN	150680	1700	---	71.3	36.4	185	< 10	< 6.0	3.7	0.4	0.3	0.15	1.05	2.0	0.69	42
EFK INDIAN	230780	1200	0.1250	95.5	45.3	131	< 10	---	10.5	0.8	2.0	0.44	0.76	0.7	0.29	61
EFK INDIAN	230780	2300	---	93.0	43.8	149	< 10	---	10.9	0.8	1.9	0.55	0.75	1.5	0.58	48
EFK INDIAN	240780	0710	---	92.8	44.2	147	< 10	---	11.2	0.9	2.0	0.56	0.70	0.6	0.41	76

Table 19, continued.

Site	Date Month Year	Time	Discharge (m^3/s)	Specific Conductance (µ mhos)	Alkalinity as $CaCO_3$ (mg/l)	Orthophosphate-P† (µg/l)	Nitrate-N (µg/l)	Sulfate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Dissolved Organic Carbon (mg/l)*	Suspended Sediment (mg/l)	Particulate Organic Matter (mg/l)	Seston Percent Organic
PUNGO CR	271079	0900	0.0777	106.6	55.2	---	40	---	14.2	1.3	2.4	0.25	0.67	0.2	0.09	64
PUNGO CR	030380	1100	0.0740	119.8	56.8	124	30	6.9	16.5	1.4	2.5	0.20	0.74	0.2	0.08	68
PUNGO CR	230480	0900	0.6810	62.4	28.8	137	20	< 6.0	7.6	0.5	1.3	0.48	2.19	9.7	3.48	38
PUNGO CR	120580	1845	0.5690	56.1	28.4	122	< 10	< 6.0	5.3	0.4	0.3	0.11	1.80	1.8	0.44	35
PUNGO CR	170580	1545	0.4340	59.6	30.1	133	< 10	< 6.0	9.3	0.6	0.7	0.18	1.21	2.4	0.51	30
PUNGO CR	150680	1745	0.2100	71.1	37.1	176	< 10	< 6.0	7.4	0.6	0.3	0.12	1.10	1.3	0.65	56
PUNGO CR	240780	1530	0.1190	108.9	52.8	125	< 10	---	15.1	0.9	1.4	0.24	0.53	0.6	0.31	66
TEAPOT CR	030380	1430	0.0120	107.0	44.5	131	300	7.0	14.2	0.9	3.5	0.21	1.30	2.8	1.54	59
TEAPOT CR	230480	1530	0.0980	66.8	22.2	171	270	< 6.0	12.0	0.7	2.7	0.41	1.39	8.4	3.46	43
TEAPOT CR	120580	1615	0.0860	50.5	21.8	128	180	< 6.0	3.9	0.3	0.6	0.11	1.81	2.2	0.87	46
TEAPOT CR	170580	1630	0.0642	58.5	24.6	129	130	< 6.0	7.1	0.4	0.7	0.16	1.01	1.1	0.27	39
TEAPOT CR	150680	1830	---	72.8	37.7	161	120	< 6.0	9.5	0.7	1.1	0.21	0.90	0.2	0.30	73
TEAPOT CR	240780	1900	0.0041	92.6	39.3	124	180	---	10.7	0.5	2.3	0.18	0.42	0.9	0.51	63
MARBLE CK	281079	1630	1.1860	64.8	30.5	---	50	---	9.2	0.4	2.7	0.49	0.59	0.7	0.19	51
MARBLE CK	030380	1600	2.1410	71.6	31.3	134	40	< 6.0	8.6	0.3	2.8	0.16	0.99	3.1	0.15	14
MARBLE CK	230480	1730	23.6760	39.4	16.6	132	50	6.7	0.9	0.0	0.3	0.14	2.49	29.4	4.91	18
MARBLE CK	120580	1710	14.5610	37.4	16.3	138	< 10	< 6.0	2.8	0.1	0.4	0.12	2.07	3.9	0.74	20
MARBLE CK	170580	1830	11.5530	36.9	17.2	143	< 10	< 6.0	4.1	0.2	0.4	0.14	1.54	4.4	0.91	26
MARBLE CK	160680	1030	---	50.2	25.3	171	< 10	< 6.0	2.5	0.1	0.3	0.11	1.25	2.5	0.89	42
MARBLE CK	250780	1000	2.4020	51.1	23.6	172	< 10	---	5.3	0.1	1.5	0.30	0.58	1.7	0.61	49
LITTLE CK	291079	1300	0.0051	164.2	84.0	---	70	---	33.8	1.8	1.7	0.68	1.15	0.6	0.28	60
LITTLE CK	040380	1230	0.0036	172.8	84.0	168	< 10	7.1	34.4	1.6	1.7	0.79	1.47	0.5	0.16	55
LITTLE CK	200480	1000	---	135.8	64.0	151	150	8.9	21.0	1.0	1.9	0.83	3.33	3.7	1.33	40
LITTLE CK	200480	1200	0.0569	122.0	64.0	142	140	9.6	20.7	0.4	1.7	0.70	3.37	---	---	---
LITTLE CK	200480	2300	---	126.8	---	140	180	8.8	19.0	1.0	1.8	1.18	2.68	50.3	21.46	43
LITTLE CK	210480	0730	---	138.8	61.6	146	320	8.6	14.1	0.7	1.0	0.29	2.50	16.2	7.25	46
LITTLE CK	240480	1030	0.1860	---	---	---	---	---	---	---	---	---	---	93.2	36.10	39
LITTLE CK	130580	1645	0.0262	97.9	44.9	143	60	8.2	11.9	0.5	0.5	0.11	2.35	5.3	2.56	51
LITTLE CK	180580	1410	---	104.1	46.0	149	50	< 6.0	16.8	0.7	0.8	0.40	2.21	4.0	1.51	42
LITTLE CK	180580	2135	---	104.9	46.2	142	60	< 6.0	13.5	0.6	0.4	0.16	2.21	6.1	2.30	42
LITTLE CK	190580	0223	---	104.4	46.3	138	72	6.9	14.9	0.6	0.5	0.16	1.93	4.6	1.79	42
LITTLE CK	190580	0815	0.0863	104.6	45.6	152	70	6.8	10.3	0.4	0.3	0.16	1.83	7.1	4.41	63
LITTLE CK	160680	1200	---	98.5	49.8	151	< 10	6.1	10.0	0.3	0.3	0.10	1.57	2.9	1.27	48
LITTLE CK	250780	1700	0.0104	143.0	69.2	137	30	---	19.7	1.2	2.0	0.33	1.15	1.8	0.84	54

Table 19, continued.

Site	Date Month Year	Time	Discharge (m^3/s)	Specific Conductance (µ mhos)	Alkalinity as $CaCO_3$ (mg/l)	Orthophosphate-P^{+} (µg/l)	Nitrate-N (µg/l)	Sulfate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Dissolved Organic Carbon (mg/l)*	Suspended Sediment (mg/l)	Particulate Organic Matter (mg/l)	Seston Percent Organic
MF LITTLE	291079	1600	17.7690	90.0	---	---	---	---	---	---	---	---	0.87	0.8	0.30	54
MF LITTLE	040380	1400	13.2120	97.2	43.0	142	< 10	7.0	11.7	0.8	2.4	0.16	0.51	1.1	0.44	51
MF LITTLE	200480	0930	74.2130	75.9	32.4	118	50	7.1	9.4	0.2	1.6	0.42	2.25	---	---	---
MF LITTLE	200480	1205	72.6240	73.3	32.4	107	30	<6.0	8.9	0.5	1.5	0.23	2.54	18.8	5.23	29
MF LITTLE	200480	2330	92.7020	69.9	26.4	117	30	<6.0	8.5	0.5	1.3	0.20	2.69	93.3	19.05	21
MF LITTLE	210480	0245	92.2610	---	---	---	---	---	---	---	---	---	---	48.2	10.53	22
MF LITTLE	240480	1100	109.6900	---	---	---	---	---	---	---	---	---	---	15.2	5.64	38
MF LITTLE	130580	1730	147.1920	54.3	23.8	151	< 10	<6.0	5.1	0.3	0.4	0.11	2.51	2.9	1.17	46
MF LITTLE	180580	1400	136.8440	53.4	23.4	106	< 10	<6.0	3.9	0.2	0.3	0.17	2.02	3.1	1.21	53
MF LITTLE	180580	2135	148.3920	52.1	23.4	116	< 10	<6.0	4.1	0.2	0.3	0.19	2.04	4.1	1.10	32
MF LITTLE	190580	0300	144.3420	52.7	23.8	122	4	<6.0	4.6	0.3	0.2	0.17	1.92	4.3	1.17	32
MF LITTLE	190580	0845	147.0650	52.3	23.4	132	< 10	<6.0	7.9	0.4	0.9	0.41	2.01	4.1	1.23	34
MF LITTLE	160680	1230	135.9400	45.2	21.8	154	< 10	<6.0	2.1	0.2	0.2	0.04	1.71	2.4	0.86	42
MF LITTLE	250780	1800	32.9620	76.6	34.0	106	< 10	---	8.8	0.4	1.6	0.19	0.77	0.9	0.39	54
L LOON MOUTH	301079	1400	0.3990	132.6	65.0	---	70	---	17.1	1.6	3.9	0.13	0.63	2.5	0.95	45
L LOON MOUTH	040380	2200	---	155.8	68.1	673	200	8.0	19.2	1.8	3.7	0.37	1.05	6.4	1.63	29
L LOON MOUTH	050380	0900	---	152.8	---	209	130	7.8	18.2	1.8	2.2	0.30	0.84	4.1	1.06	31
L LOON MOUTH	050380	1600	0.4160	151.6	69.4	183	20	8.0	17.1	1.8	3.8	0.34	0.83	4.8	1.10	28
L LOON MOUTH	240480	1900	3.8400	118.3	49.9	207	230	9.1	18.2	1.5	3.4	1.05	3.44	404.2	53.06	13
L LOON MOUTH	250480	1000	---	---	---	190	190	10.4	36.4	2.9	6.7	2.67	3.07	181.2	28.62	16
L LOON MOUTH	250480	1630	---	117.2	49.4	213	190	10.1	20.3	1.7	4.0	1.44	2.60	---	---	---
L LOON MOUTH	140580	1148	2.4040	86.0	42.3	198	80	7.8	10.9	0.8	3.6	0.17	1.73	130.4	13.08	11
L LOON MOUTH	140580	2108	2.5940	85.1	42.8	198	200	7.9	7.4	0.6	0.9	0.13	2.19	129.9	9.75	9
L LOON MOUTH	150580	1050	2.3130	89.1	40.9	202	90	8.0	12.4	1.0	4.1	0.22	1.74	212.2	25.19	12
L LOON MOUTH	190580	1618	---	89.3	43.7	256	70	6.6	8.9	0.7	1.5	0.16	1.72	47.6	5.28	12
L LOON MOUTH	190580	2238	2.3620	93.5	44.3	217	60	6.9	8.7	0.7	1.2	0.14	1.75	75.3	21.19	25
L LOON MOUTH	200580	0818	---	88.7	37.6	244	70	7.0	9.3	0.9	1.8	0.31	1.75	54.9	9.45	18
L LOON MOUTH	160680	1700	---	86.0	41.3	298	< 10	6.2	8.4	0.7	1.9	0.26	1.55	52.2	5.65	11
L LOON MOUTH	260780	1230	---	117.8	51.9	222	30	---	12.7	1.2	4.7	0.44	1.52	22.0	5.63	21
L LOON MOUTH	260780	1745	---	117.2	56.2	246	30	---	12.8	1.1	4.6	0.47	1.37	27.1	4.54	18
L LOON MOUTH	270780	1030	1.0220	121.2	55.8	254	40	---	13.0	1.2	4.1	0.31	1.30	20.9	3.70	19
EFK L LOON	301079	1700	0.3070	138.2	67.3	---	50	---	18.4	1.2	4.6	0.22	---	4.0	1.18	34
EFK L LOON	250480	1200	3.1990	123.0	53.4	198	150	10.3	33.0	2.6	5.0	1.56	3.41	134.2	17.54	13
EFK L LOON	140580	1700	2.0080	90.5	44.0	202	80	8.4	8.3	0.7	2.7	0.23	1.96	118.6	11.31	10
EFK L LOON	200580	1315	1.8930	93.1	43.9	237	50	<6.0	8.3	0.9	2.0	0.16	1.63	56.0	6.18	12
EFK L LOON	160680	1530	---	87.2	44.8	342	90	6.8	7.7	0.7	2.4	0.28	1.48	37.6	4.69	13
EFK L LOON	270780	1415	0.8610	119.5	57.1	276	< 10	---	13.6	1.3	5.6	0.54	1.50	---	---	---

Table 19, continued.

Site	Date Month Year	Time	Discharge (m^3/s)	Specific Conductance (μ mhos)	Alkalinity as $CaCO_3$ (mg/l)	Orthophosphate-P† (μg/l)	Nitrate-N (μg/l)	Sulfate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Dissolved Organic Carbon (mg/l)*	Suspended Sediment (mg/l)	Particulate Organic Matter (mg/l)	Seston Percent Organic
WFK L LOON	301079	1609	0.0920	127.6	54.2	---	90	---	18.4	0.9	2.3	0.11	0.46	2.9	1.40	54
WFK L LOON	050380	1400	0.0800	119.4	53.8	127	90	7.0	14.1	0.8	2.2	0.13	0.64	1.2	0.71	67
WFK L LOON	250480	1643	0.6450	79.4	33.0	177	160	9.7	10.5	0.6	1.3	0.31	2.44	17.4	6.45	38
WFK L LOON	140580	1643	0.5860	72.9	33.5	150	70	7.2	7.0	0.3	0.5	0.11	1.85	4.9	1.50	32
WFK L LOON	200580	1222	0.4690	75.5	35.2	181	60	< 6.0	8.3	0.4	0.4	0.11	1.52	3.2	1.68	57
WFK L LOON	160680	1500	---	77.5	---	165	30	6.4	4.9	0.3	0.2	0.11	1.10	3.3	1.74	56
WFK L LOON	270780	1350	0.1860	102.4	48.2	148	40	---	15.8	0.7	2.2	0.16	0.79	2.9	1.52	56
CHAR CK	301079	1600	0.0019	123.6	47.5	---	230	---	16.0	1.4	3.2	0.15	0.85	0.7	0.54	78
CHAR CK	050380	1500	0.0074	91.4	43.2	176	450	8.6	13.3	1.0	2.5	0.31	1.26	0.1	0.01	---
CHAR CK	250480	1412	0.2122	---	---	226	240	11.3	10.3	0.7	1.3	0.67	3.24	31.1	9.48	31
CHAR CK	140580	1830	0.0899	69.7	28.2	249	180	7.8	9.4	0.6	1.6	0.23	2.17	5.0	1.70	39
CHAR CK	200580	1345	0.0609	70.9	30.9	243	190	6.5	9.5	0.8	1.3	0.32	2.11	2.4	1.11	50
CHAR CK	160680	1600	---	---	---	254	270	6.7	8.0	0.5	0.9	0.25	1.87	1.6	1.18	76
CHAR CK	270780	1706	0.0070	94.6	40.8	237	260	---	12.4	0.8	2.9	0.46	1.47	1.9	0.65	43
MF PINE	011179	1235	18.1700	90.6	41.5	---	40	---	11.2	0.8	2.2	0.17	1.06	0.9	0.27	46
MF PINE	050380	0900	13.6310	105.0	42.7	---	110	7.2	9.9	0.8	2.6	0.17	0.61	1.2	0.50	50
MF PINE	250480	1630	110.1900	---	---	116	20	< 6.0	7.9	0.5	0.8	0.30	2.86	17.6	4.41	26
MF PINE	150580	1445	151.0480	55.4	24.1	110	<10	---	---	---	---	---	2.42	4.1	1.23	35
MF PINE	200580	1750	149.4390	46.3	22.6	121	<10	< 6.0	5.6	0.4	0.4	0.16	2.44	8.8	1.99	26
MF PINE	160680	1830	---	50.5	23.6	155	<10	< 6.0	3.7	0.3	0.4	0.46	1.66	3.6	1.63	50
MF PINE	280780	1200	33.9840	80.8	36.5	141	<10	---	11.2	0.6	1.8	0.15	0.61	1.7	0.72	51
WHITE CR	011179	2300	0.0426	219.0	101.2	---	290	---	38.3	2.3	5.8	0.57	0.86	0.3	0.11	60
WHITE CR	060380	1500	0.0434	192.2	86.8	215	20	7.4	33.9	1.6	4.1	0.52	1.48	0.6	0.39	74
WHITE CR	250480	1700	0.4469	100.9	48.5	160	<10	< 6.0	12.1	0.5	1.4	0.56	3.76	10.3	3.66	37
WHITE CR	150580	1710	0.2096	100.6	48.0	166	<10	< 6.0	10.3	0.4	1.0	0.12	2.05	4.7	2.30	46
WHITE CR	200580	1935	0.1790	106.1	50.5	185	<10	< 6.0	11.2	0.5	1.1	0.23	1.74	2.7	0.85	38
WHITE CR	170680	1900	---	126.1	61.0	226	<10	< 6.0	1.9	0.1	0.2	0.10	2.21	1.9	1.02	58
WHITE CR	280780	1945	0.0218	168.1	88.4	184	50	---	29.8	1.4	4.3	0.59	0.96	0.9	0.45	59

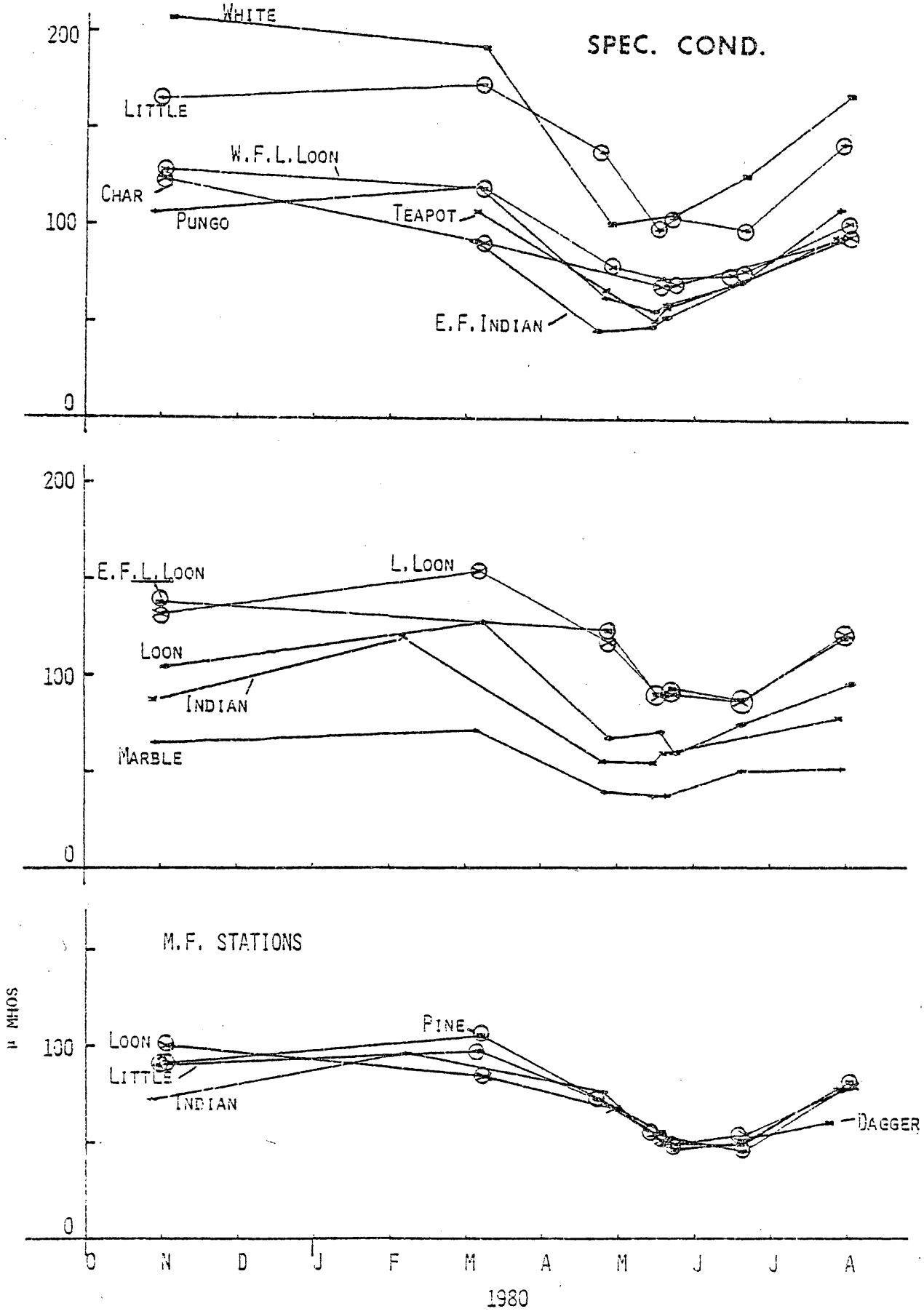
*Dissolved organic carbon concentrations are provisional, contingent on transformation refinements of analyser standard curves.

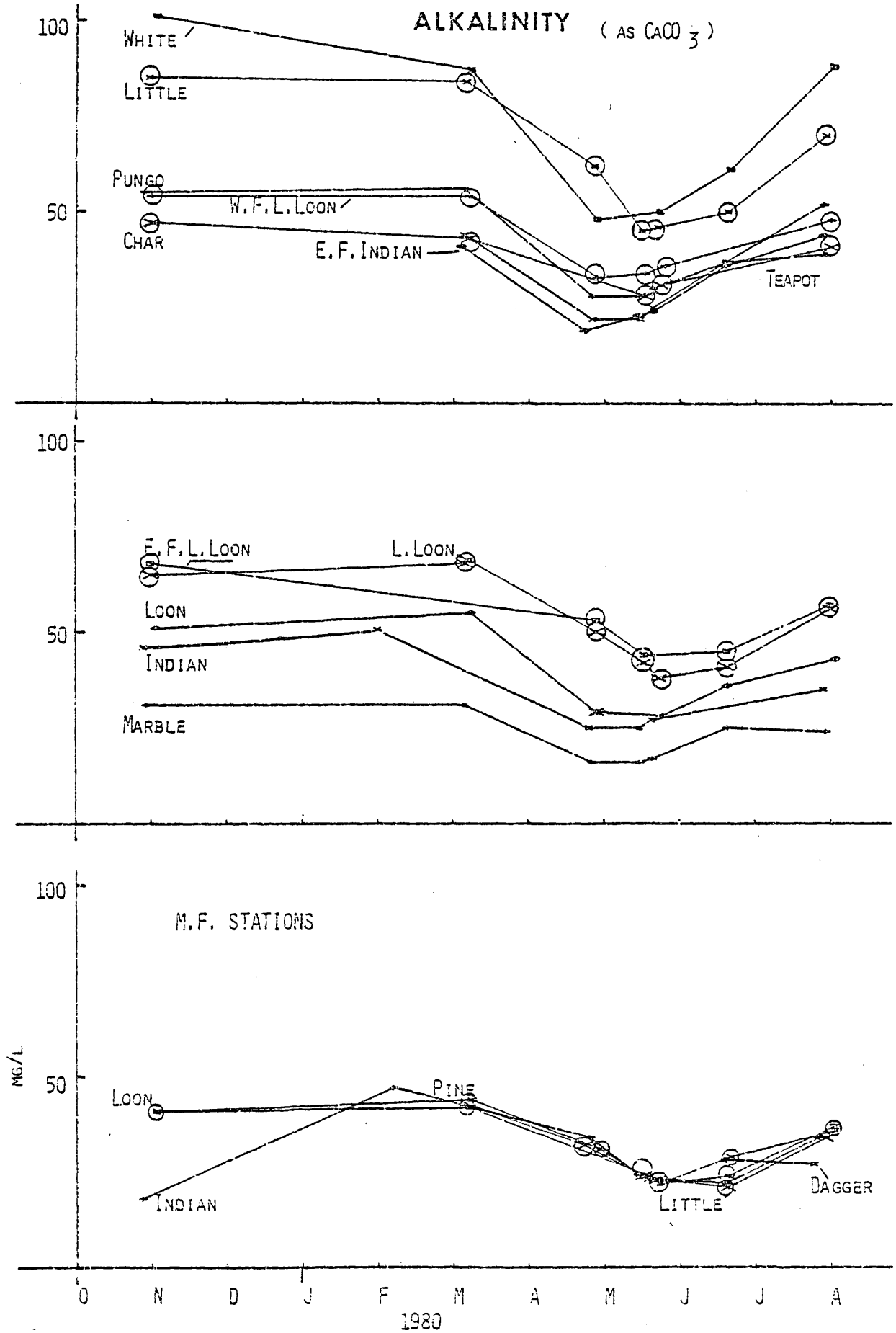
†Orthophosphate concentrations are higher than expected for these Idaho Batholith streams. In spite of rigorous scrutiny, no abnormalities could be detected in the procedure, which was carefully followed in our lab.

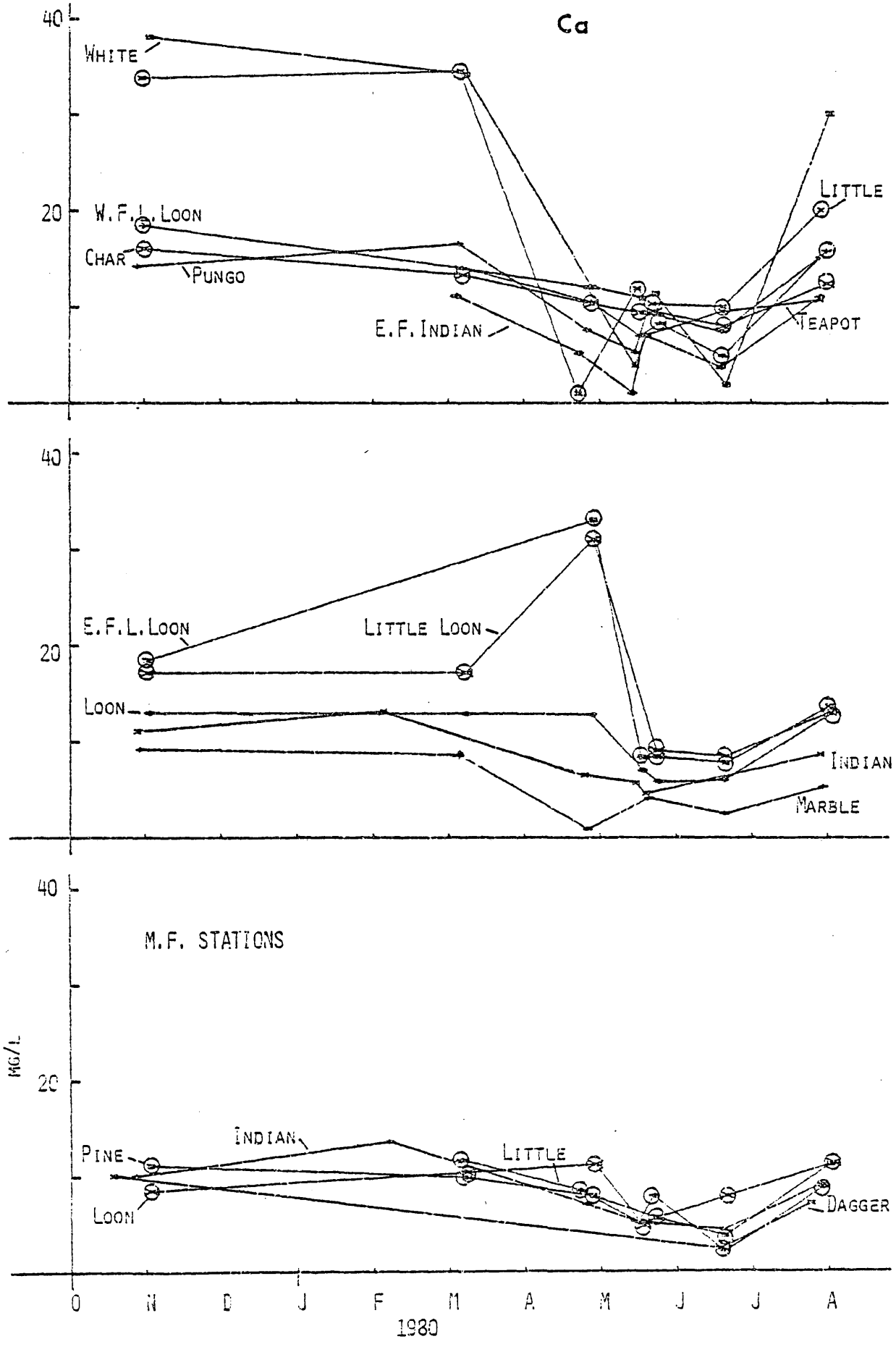
Table 19, continued.

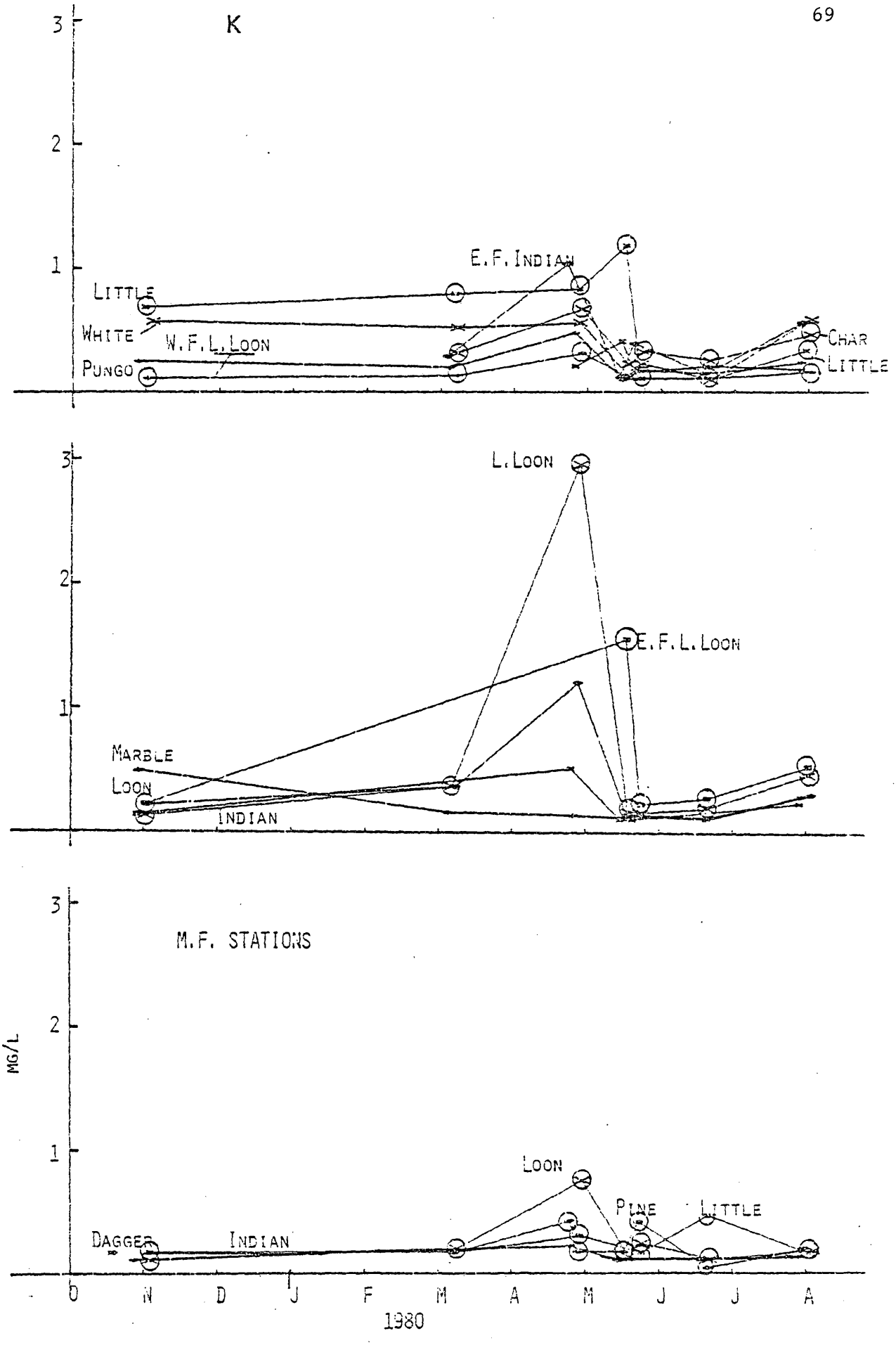
Site	Date Month Year	Time	Discharge (m^3/s)	Specific Conductance (µmhos)	Alkalinity as $CaCO_3$ (mg/l)	Orthophosphate-P (µg/l)	Nitrate-N (µg/l)	Sulfate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Dissolved Organic Carbon (mg/l)*	Suspended Sediment (mg/l)	Particulate Organic Matter (mg/l)	Seston Percent Organic
MF LOON	021179	1517	18.2100	100.8	40.7	---	60	---	8.6	0.6	1.6	0.11	0.98	1.0	0.41	54
MF LOON	060380	1745	13.6700	83.4	44.0	124	<10	7.3	10.4	0.8	2.7	0.20	0.63	0.8	0.30	51
MF LOON	250480	2000	110.6400	---	---	98	20	< 6.0	10.2	0.7	1.4	1.33	3.09	9.9	3.17	34
MF LOON	260480	1420	110.6400	66.7	31.0	112	<10	< 6.0	11.2	0.7	1.4	0.51	2.79	15.8	4.20	28
MF LOON	150580	1000	151.0500	50.5	23.4	134	<10	< 6.0	4.8	0.3	0.3	0.13	2.16	4.3	1.53	41
MF LOON	200580	2000	149.4400	49.0	22.4	115	<10	< 6.0	5.6	0.4	0.4	0.24	1.60	5.7	2.16	41
MF LOON	170680	1130	---	53.5	29.0	149	<10	< 6.0	7.9	0.1	0.2	0.11	2.11	5.0	1.77	39
MF LOON	290780	1400	33.9800	79.4	36.6	125	<10	---	11.3	0.6	1.9	0.18	0.80	2.1	0.65	40
LOON	021179	1930	4.3600	103.6	50.7	---	40	---	13.1	1.2	8.3	0.22	0.19	1.7	0.44	37
LOON	060380	1900	2.8220	126.6	54.6	212	<10	8.9	12.9	1.0	5.3	0.37	0.55	0.9	0.29	48
LOON	250480	1400	---	67.4	29.7	213	30	< 6.0	12.8	0.8	2.5	1.21	2.40	21.6	3.59	18
LOON	150580	1025	---	70.7	33.2	149	<10	< 6.0	7.0	0.4	0.8	0.14	1.63	9.5	1.67	20
LOON	210580	0715	---	59.5	28.7	159	<10	6.9	5.8	0.4	0.5	0.14	2.38	25.6	3.56	15
LOON	160680	1130	---	73.7	36.5	203	<10	< 6.0	6.3	0.3	0.6	0.12	1.43	5.6	1.24	26
LOON	290780	2130	9.5201	94.5	43.1	154	<10	---	13.1	0.7	3.6	0.31	.75	2.2	.59	36
MF BIG CK	280480	1700	---	63.5	30.3	107	<10	< 6.0	14.0	0.7	2.6	0.43	2.72	20.2	4.74	25
MF BIG CK	220580	1330	---	50.0	26.6	87	<10	< 6.0	5.5	0.3	0.4	0.19	2.14	29.2	7.33	26
MF BIG CK	180680	1230	---	51.2	22.8	112	<10	6.4	1.3	0.1	0.2	0.10	1.96	7.6	2.50	34
MF BIG CK	010880	1400	---	85.1	43.3	137	<10	---	12.7	1.2	2.5	0.28	0.85	2.7	0.78	36
BIG CK	041179	1445	---	124.0	50.4	---	70	---	14.7	2.7	0.9	0.37	0.48	0.5	0.14	54
BIG CK	280480	1700	---	63.5	30.3	94	<10	< 6.0	7.4	0.6	1.2	0.42	3.98	11.6	4.29	38
BIG CK	220580	1330	---	50.0	21.2	94	<10	< 6.0	4.0	0.5	0.3	0.15	1.78	20.2	3.75	20
BIG CK	180680	1300	---	51.2	22.9	125	<10	6.1	1.7	0.3	0.2	0.10	1.67	4.4	1.35	35
BIG CK	010880	1500	---	94.9	45.7	133	<10	---	13.3	2.0	1.4	0.51	0.73	1.4	0.73	57
MF MOUTH	051179	1430	---	105.0	46.3	---	50	---	16.0	1.2	3.6	0.68	0.91	0.5	0.19	58
MF MOUTH	280480	1700	---	63.1	28.1	100	<10	< 6.0	9.3	0.5	1.5	0.19	2.68	20.2	5.01	26
MF MOUTH	230580	1600	---	46.2	21.1	102	<10	6.5	4.3	0.3	0.1	0.13	2.17	50.7	8.66	18
MF MOUTH	190680	1200	---	51.5	18.8	126	<10	6.8	7.8	0.5	0.7	0.14	1.78	8.6	2.38	30
MF MOUTH	020880	1445	---	87.8	40.3	154	<10	---	12.8	1.0	2.4	0.25	0.89	1.6	0.52	44

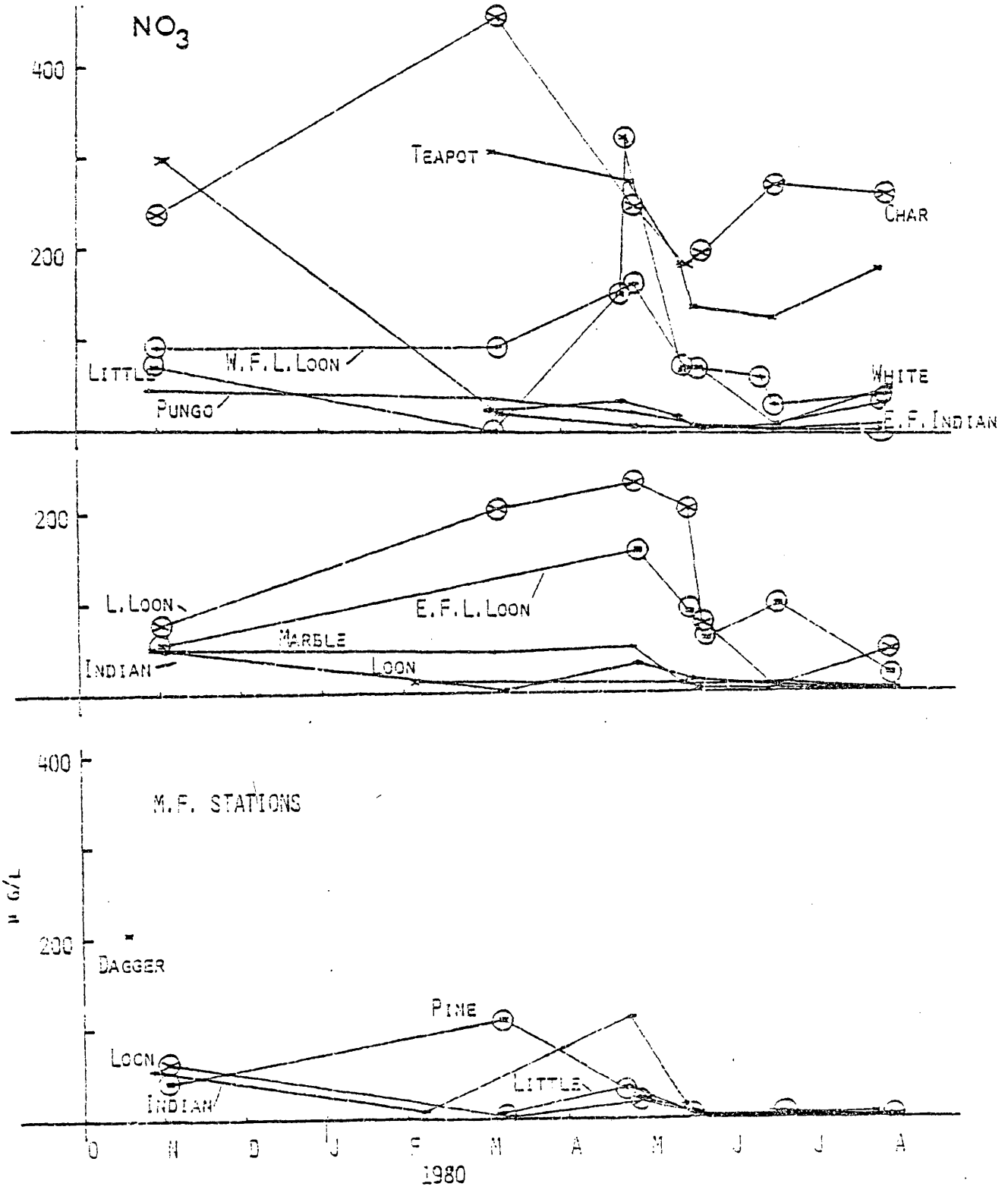
Figure 8. Concentrations of selected water quality constituents at regular sampling sites of the Mortar Creek Fire study: (a) specific conductance (spec. cond.), (b) alkalinity, (c) calcium (Ca), (d) potassium (K), (e) nitrate nitrogen (NO_3), (f) dissolved organic carbon (DOC), (g) suspended sediment.

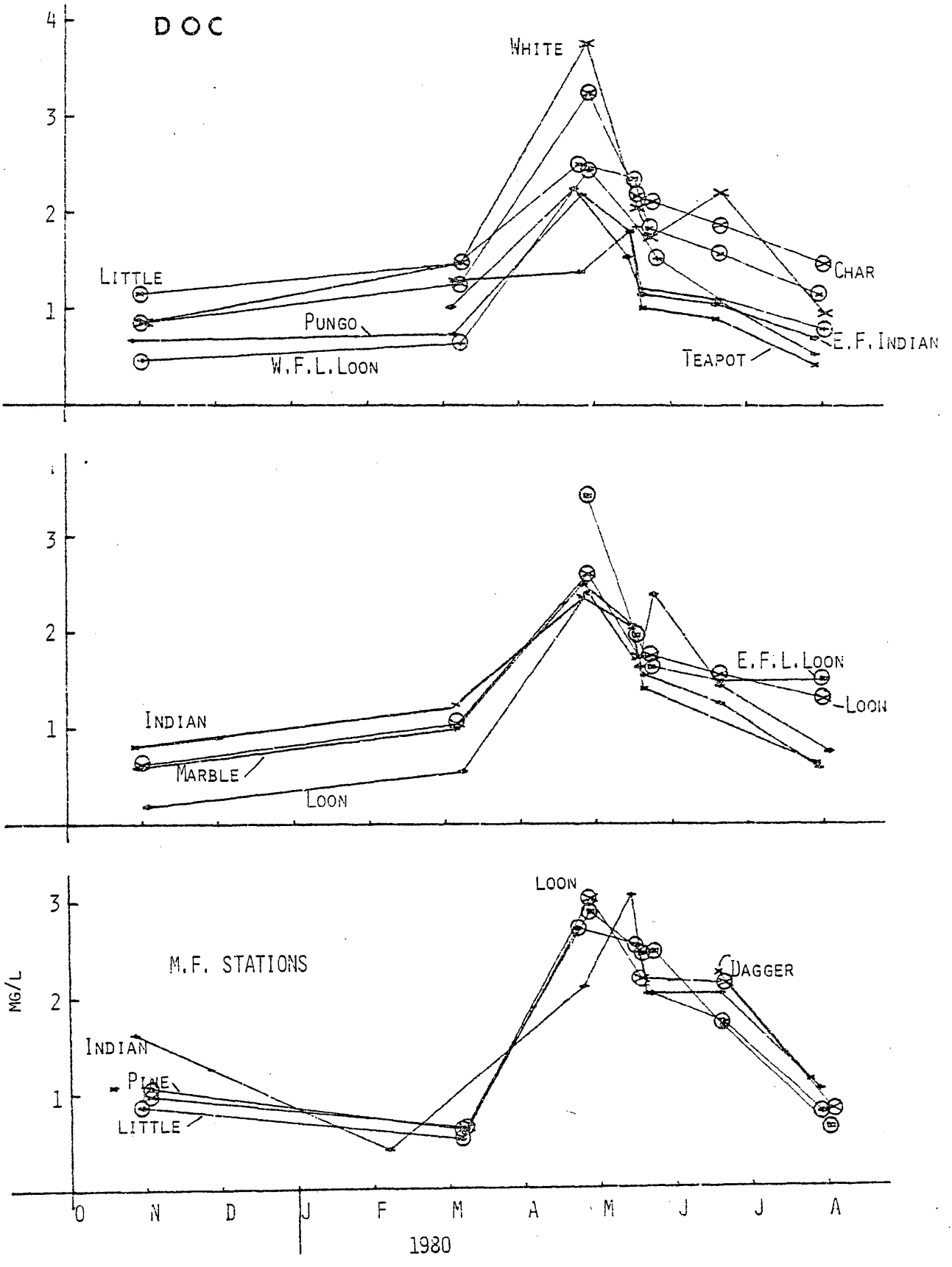

SPEC. COND.
WHITE
LITTLE
W.F.L.LOON
CHAR
PUNGO
TEAPOT
E.F.INDIAN
200
100
0
E.F.L.LOON
L.LOON
LOON
INDIAN
MARBLE
M.F. STATIONS
PINE
LOON
LITTLE
INDIAN
DAGGER
SOHM
O N D J F M A M J J A
1980

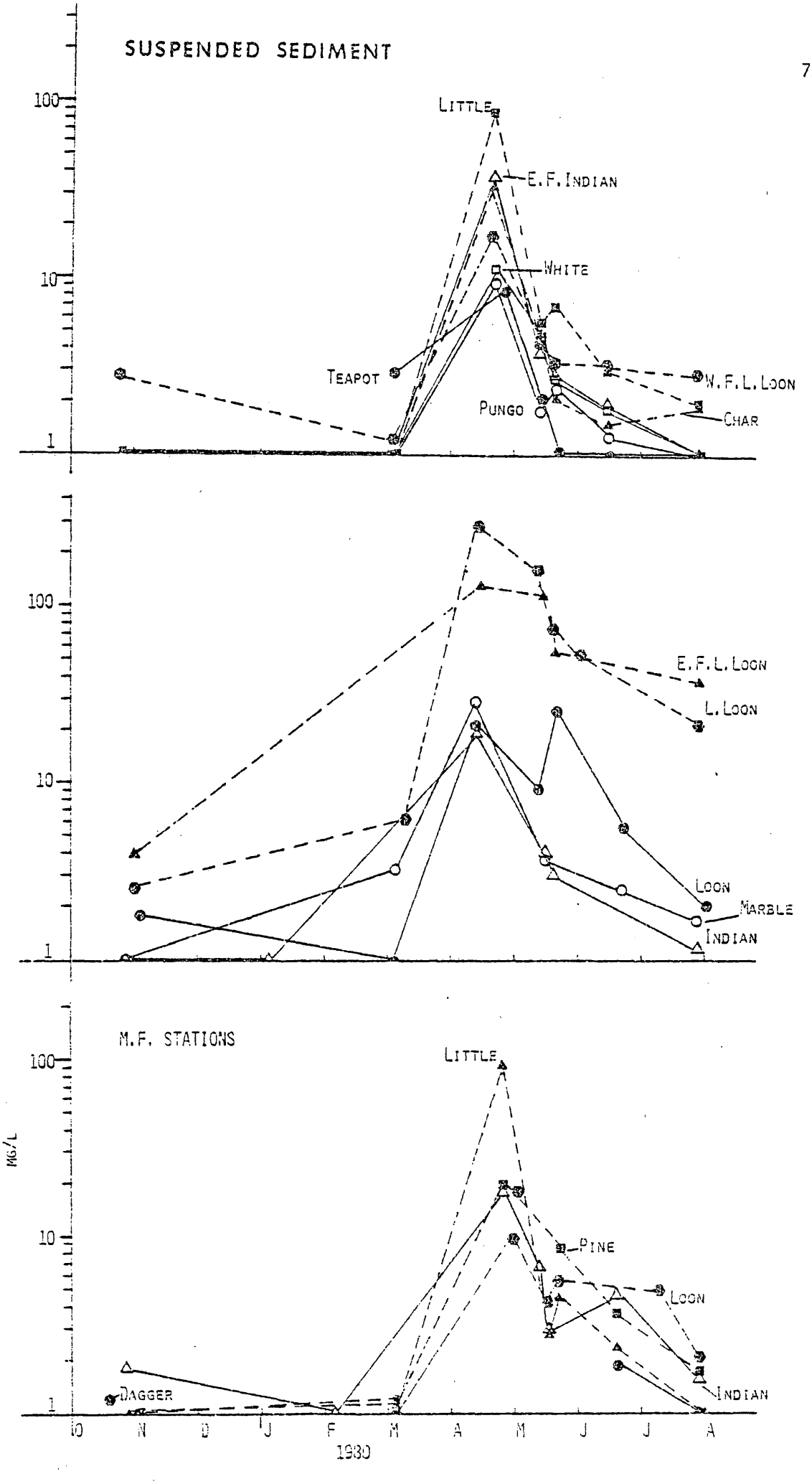

ALKALINITY (AS CaCO 3)
100
50
WHITE
LITTLE
PUNGO
W.F.L. LOON
CHAR
E.F. INDIAN
TEAPOT
100
50
E.F.L. LOON
L. LOON
LOON
INDIAN
MARBLE
100
M.F. STATIONS
MG/L
50
LOON
PINE
INDIAN
LITTLE
DAGGER
O
N
D
J
F
M
A
M
J
J
A
1980


Ca
40
20
WHITE
W.F.L. LOON
CHAR
PUNGO
E.F. INDIAN
LITTLE
TEAPOT
E.F.L. LOON
LITTLE LOON
LOON
INDIAN
MARBLE
M.F. STATIONS
MG/L
PINE
INDIAN
LOON
LITTLE
DAGGER
O
N
D
J
F
M
A
M
J
J
A
1980


K
3
2
1
E.F. INDIAN
LITTLE
WHITE
W.F.L. LOON
PUNGO
CHAR
LITTLE
3
2
1
L. LOON
E.F.L. LOON
MARBLE
LOON
INDIAN
3
2
1
M.F. STATIONS
MG/L
LOON
PINE
LITTLE
DAGGER
INDIAN
O
N
D
J
F
M
A
M
J
J
A
1980


NO3
400
200
TEAPOT
CHAR
LITTLE
W.F.L. LOON
PUNGO
WHITE
E.F. INDIAN
200
L. LOON
E.F.L. LOON
MARBLE
INDIAN
LOON
400
M.F. STATIONS
200
DAGGER
PINE
LOON
LITTLE
INDIAN
O
N
D
J
F
M
A
M
J
J
A
1980


DOC
WHITE
LITTLE
PUNGO
W.F.L.LOON
CHAR
E.F.INDIAN
TEAPOT
INDIAN
MARBLE
LOON
E.F.L.LOON
LOON
M.F. STATIONS
LOON
DAGGER
INDIAN
PINE
LITTLE
MG/L
4
3
2
1
O
N
D
J
F
M
A
M
J
J
A
1980


SUSPENDED SEDIMENT
100
10
1
LITTLE
E.F. INDIAN
WHITE
TEAPOT
PUNGO
W.F.L. LOON
CHAR
100
10
1
E.F.L. LOON
L. LOON
LOON
MARBLE
INDIAN
M.F. STATIONS
MG/L
100
10
1
LITTLE
PINE
LOON
DAGGER
INDIAN
O
N
D
J
F
M
A
M
J
J
A
1980

outcroppings also had high values of calcium, e.g., Jackass Creek measured 23 to 39 mg/l.

Unlike most other minerals, potassium reached its highest concentrations during spring runoff (Fig. 8). However, values generally were low, with most less than 1 mg/l. In general, the burn tributaries had higher levels of nitrate than the controls. Notable exceptions were White and Teapot Creek where nitrate was higher than in any of the burn streams besides Char Creek, and Little Loon Creek which showed highly variable values. A number of streams (mostly controls) had very low levels in summer suggesting the potential for this important nutrient to limit algal growth in unperturbed systems. There were no distinct differences in dissolved organic carbon (DOC) between burn and control streams (Fig. 8). Concentrations of DOC showed a direct relation with flow as did those of suspended solids. In the small tributaries, suspended solids peaked in April and dropped to intermediate levels during May whereas in the medium streams high levels continued through May as a result of delayed snowmelt from streams at higher elevations. The burn tributaries showed consistently higher concentrations of suspended solids than the controls. In particular, the Little Loon values are on order of magnitude above those of the mid-sized control streams.

Alkalinity, calcium, magnesium, and sodium all showed statistically significant correlations with specific conductance whereas phosphate, nitrate, and potassium did not (Table 20). The reasons for the lack of correlation of the latter group are: (1) their low concentrations (generally <1 mg/l) cause them to contribute very little to specific conductance and (2) their transport by water is

Table 20. Results of correlation analysis between specific conductance and dissolved ion concentration for Mortar Creek Stream Study. NS = not significant at 0.05 level. N = number of samples. All concentrations are expressed as mg/l.

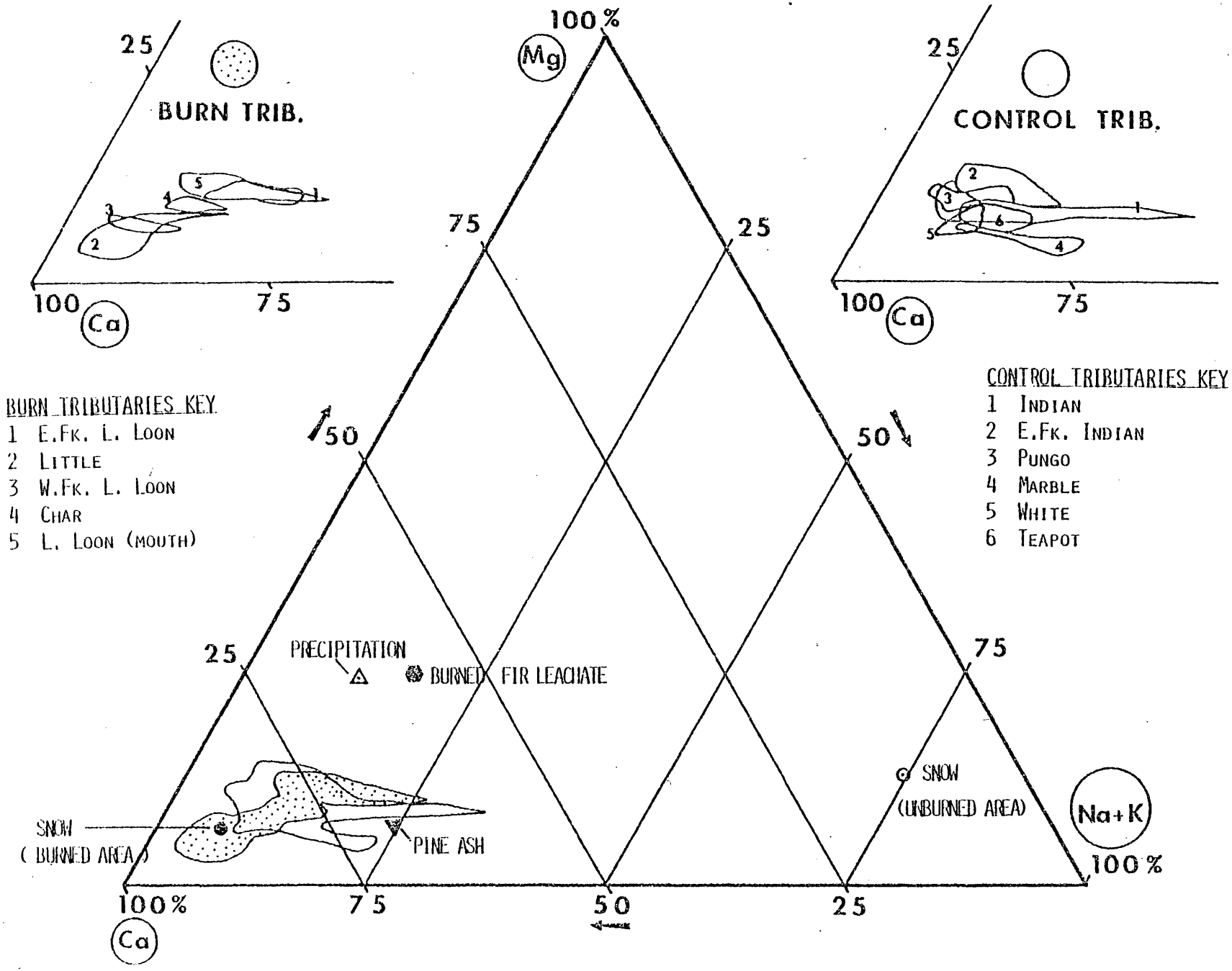
		Pearson Correlation Coefficients						
Site	N	Alkalinity	PO_4-P	NO_3-N	Calcium	Magnesium	Sodium	Potassium	DOC
MF Indian	11	0.81	-0.47	NS	0.95	0.88	0.83	0.58	-0.70
Indian	9	0.93	NS	NS	0.95	0.87	0.94	NS	-0.66
E.Fk. Indian	9	0.99	NS	NS	0.84	0.82	0.85	NS	-0.81
Pungo	7	0.99	NS	NS	0.96	0.93	0.84	NS	-0.82
Teapot	6	0.91	NS	NS	0.84	0.73	0.83	NS	NS
Marble	7	0.98	NS	NS	0.86	0.73	0.93	NS	-0.73
Little	13	0.97	NS	NS	0.89	0.90	0.78	0.59	NS
MF Little	11	0.97	NS	NS	0.91	0.78	0.96	NS	-0.57
Mouth Little Loon	16	0.96	NS	NS	0.84	0.93	0.46	NS	-0.46
E.Fk. Little Loon	6	0.96	NS	NS	NS	NS	0.86	NS	0.76
W.Fk. Little Loon	7	0.98	-0.80	NS	0.90	0.93	0.90	NS	-0.80
Char	5	0.93	NS	NS	0.98	0.92	0.92	NS	-0.96
MF Pine	5	0.98	NS	0.82	0.85	0.95	1.00	NS	-0.87
White	7	0.98	NS	0.74	0.91	0.94	0.93	NS	-0.73
MF Loon	7	0.91	NS	0.67	NS	0.70	0.80	NS	-0.66

just the opposite of that seen for conductance.

Surface water removal of cations from undisturbed drainages normally reflects the geological conditions of the watershed (Henderson et al. 1978). Potassium is an exception in that it is under biological control and is taken up by plants during the growing season (Likens et al. 1977). The anions ortho-phosphate and nitrate also are important nutrients commonly present in limited amounts and can be expected to behave similar to potassium. Hem (1960) and Gosz (1977) utilized a triangular plotting technique to analyze the interrelationships between major cations. When the Mortar Creek Fire data are analyzed in this fashion several interesting features emerge (Fig. 9). Calcium, the predominant cation, shows a broad range of values (57-93%) followed closely by that of sodium plus potassium (3-33%). Magnesium, the least abundant of the cations analyzed, had the smallest range of values (3-14%). Distribution patterns for the burn and control tributaries generally overlapped except for the extremely high percentage of calcium at Little Creek. White Creek had the highest percent calcium of the control tributaries. The highest percentage of potassium was found during April after the start of runoff but prior to leafout and consequent plant uptake. In order to understand these relationships more thoroughly one would need to quantify the chemical make-up of precipitation and soil water. However the principal observation from this analysis is that there was no major disruption in the relative composition of cations during the first year of study as a result of the Mortar Creek Fire.

In general, nutrient/sediment data collection for each of the six sampling periods was limited to single grab samples by the number of stations (20) and the restrictions to mobility imposed by site

Figure 9. Relative importance of the major cations dissolved in stream water, Mortar Creek Fire Stream Study. Stippled area in large triangular plot indicates a composite of the relative cation concentrations for all burn streams. Composite area for all control streams is represented by the clear cloud partially overlapped by the stippled (burn) cloud. Labeled points represent relative cation content of pertinent materials: Precipitation (Summer Idaho Primitive Area rainfall; Clayton 1976); Snow samples collected from ground in March 1980 (this study) near West Fork Little Loon Creek (Burned Area) and at Little Creek Guard Station (Unburned); Burned Fir Leachate composition is from soil water of Lubrecht Fire Study, Montana (Stark 1977); Pine Ash Composition calculated from data given by Wise (1946). Small upper figures provide enlarged detail of burn (left) and control (right) cation clouds. Cation clouds are shown for the individually numbered study streams. Cation concentrations (mg/l) were converted to chemical equivalents prior to calculation of percentages.


100 %
Mg
25
BURN TRIB.
75
25
100
Ca
75
25
CONTROL TRIB.
100
Ca
75
BURN TRIBUTARIES KEY
1 E.Fk. L. Loon
2 Little
3 W.Fk. L. Loon
4 Char
5 L. Loon (mouth)
CONTROL TRIBUTARIES KEY
1 Indian
2 E.Fk. Indian
3 Pungo
4 Marble
5 White
6 Teapot
50
50
25
75
PRECIPITATION
BURNED FIR LEACHATE
SNOW
(BURNED AREA)
PINE ASH
SNOW
(UNBURNED AREA)
Na+K
100 %
100 %
75
50
25
Ca

access in this wilderness area. To estimate how representative the grab samples were of the parameters being quantified, multi-sample collections were taken whenever possible. On 12 occasions several (3-5) samples were collected for each constituent over a short (20-72 h.) time period. The coefficients of variation (CV) for these multi-sample series are shown in Table 21 . As expected, variance was generally lowest during base flow periods (March and July) and highest during runoff (April-May) when discharge fluctuates on both a diel and a daily basis. Variance was highest for particulates (10-100%) and lowest for the major indicator of dissolved constituents (specific conductance and alkalinity (0-16%). The cations (Ca, Mg, Na, K) consistently varied 20-75% during the runoff period.

Table 21. Variations in chemical constituents over short time intervals (1 to 3 d).*

Site	Date	N	Coefficients of Variation (%) SC	Alk	PO_4-P	NO_3-N	Ca	Mg	Na	K	DOC	SS	POM
Indian	7-23-80	4	16.24	15.94	20.31	22.22	33.36	10.53	54.25	6.74	43.72	55.73	50.69
EF Indian	7-23-80	3	1.60	1.75	6.93	16.67	3.23	6.93	2.94	12.89	4.36	52.85	34.15
Little	4-20-80	4	6.08	2.19	3.35	41.90	4.85	37.06	25.52	49.01	14.99	103.08	103.32
	5-18-80	4	0.32	0.67	4.40	12.99	19.75	21.88	43.20	54.55	9.53	25.88	52.47
MF Indian	7-23-80	3	3.08	9.88	8.45	bd	0.65	0.0	3.69	4.56	17.51	10.66	12.24
Little Loon	3-5-80	3	1.41	--	77.66	75.36	5.78	0.0	27.72	10.43	13.70	23.12	25.19
	4-25-80	3	--	--	5.87	10.51	39.88	37.24	37.40	49.16	13.86	--	--
	5-14-80	3	2.42	2.34	1.16	51.94	25.07	25.00	60.05	26.01	13.93	30.08	50.76
	5-19-80	3	2.89	8.85	8.36	6.61	3.41	15.06	20.00	45.70	1.00	24.22	68.90
	7-26-80	3	1.82	4.35	6.92	14.71	1.19	4.95	7.20	20.91	8.05	14.18	20.93
MF Little	4-20-80	3	4.12	11.40	5.34	22.71	5.05	43.30	10.41	42.11	8.97	70.23	60.09
	5-18-80	4	1.09	0.85	9.15	35.36	36.55	34.82	75.33	49.81	2.66	13.89	4.87

*bd = all concentrations were below the assay's limit of detection.
N = sample size, SC = specific conductance, Alk = alkalinity, SS = suspended sediments, POM = particulate organic matter.

Relationships Between Concentration and Discharge

As noted earlier, examination of the pattern followed by the concentrations of chemical constituents over the course of a year reveals that for many (most) of the ions concentration is strongly influenced by stream flow. As discharge levels range over an order of magnitude between base and peak flows some dissolved ion concentrations vary several fold and suspended material changes by as much as 10 or even 100 times. The statistical relationships between concentration and discharge for the components analyzed in this study are shown in Table 22 .

In general, specific conductance, alkalinity, calcium, magnesium, and sodium concentrations are significantly correlated with discharge and decrease as flows are elevated by runoff. This is due to dilution by snowmelt water which has had less contact with the soil and geologic substrata than the groundwater. A model to describe the mixing of ground and precipitation water has been developed by Johnson et al. (1969). They found for their New Hampshire study streams that calcium, magnesium, and sodium were generally diluted by increased stream discharge which is in agreement with our results. On the other hand, dissolved and particulate organic carbon and total suspended sediments undergo concentration increases with elevated discharge (Table 22). The nutrients phosphate, nitrate, and potassium were not significantly correlated with flow. Biotic processes appear to be more important in regulating these ions whereas geologic processes are thought to exert the dominant regulatory force on the major cations (Henderson et al. 1978).

Table 22. Results of correlation analysis between instantaneous discharge and concentration of chemical constituents for Mortar Creek Fire Stream Study. NS = not significant at 0.05 level. L = Concentration and discharge values log transformed prior to correlation analysis.

	Pearson Correlation Coefficients											
	Cond	Alk	PO_4-P	NO_3-N	Ca	Mg	Na	K	DOC	SS	POM	% ORG
MF Indian	-0.85	NS	NS	NS	-0.90	-0.81	-0.95^L	NS	0.79	NS	NS	NS
Indian	-0.94^L	-0.96^L	NS	NS	-0.93^L	-0.82^L	-0.83^L	NS	0.95	0.91	0.94	-0.86
E.Fk. Indian	-0.96^L	-0.97^L	NS	NS	-0.89^L	-0.88^L	NS	NS	0.91^L	0.97^L	0.95^L	-0.97^L
Pungo	-0.95^L	-0.98^L	NS	NS	-0.87^L	-0.95^L	NS	NS	0.96	0.94^L	0.85^L	-0.91^L
Teapot	-0.84^L	-0.92^L	NS	NS	NS	NS	NS	NS	0.79^L	NS	NS	0.92^L
Marble	-0.90^L	-0.95^L	NS	NS	-0.92	NS	-0.98^L	-0.94^L	0.95^L	0.86^L	0.86^L	NS
Little	-0.84^L	-0.77^L	NS	0.89	-0.80	-0.86	NS	NS	0.92	0.70	0.94	NS
MF Little	-0.96	-0.95	NS	NS	-0.83	-0.70	-0.93	NS	NS	NS	NS	NS
Little Loon	-0.78^L	-0.89^L	NS	0.80	NS	-0.64	NS	NS	0.96^L	0.98^L	0.97^L	-0.81^L
W.Fk. Little Loon	-0.97^L	-0.99^L	$+0.84^L$	NS	-0.86	-0.82	-0.84	NS	0.98	0.74^L	NS	-0.82
Char	-0.98^L	-0.99^L	NS	NS	-0.92^L	-0.86^L	-0.95^L	NS	0.98^L	0.95	0.95	-0.77^L
MF Pine	-0.98^L	-0.99^L	-0.92^L	NS	-0.94	-0.98^L	-0.98	NS	0.89^L	0.86^L	0.83^L	-0.88
White	-0.88^L	-0.92^L	NS	-0.74^L	-0.89^L	-0.87^L	-0.87^L	NS	0.98	0.99	0.97	-0.79
MF Loon	-0.94	-0.98	NS	NS	NS	NS	-0.77^L	NS	0.87^L	0.88^L	0.91^L	-0.71^L

Watershed Yield

In comparing the amounts of transported material in the different streams it is important to consider the volume of flow as well as the concentration. The load of material (g/s) is equal to the concentration (g/m^3) times the discharge (m^3/s). The loading values give a good indication of the relative amounts of materials contributed to the Middle Fork by burn and control tributaries within the main study section. For example in July 1980, Little Creek alone was responsible for most of the suspended solids increase in the main stream (Fig. 10). The values for Little Loon were comparable to those of Big Loon yet Big Loon Creek carried 9 times the volume of water. In both July and April 1980, Little Loon contributed only 3% of the flow to the main river and yet it was responsible for about 45% of the suspended sediments. A similar analysis for nitrate indicates that Little Loon added about 30% to the load carried by the Middle Fork. However, while the suspended sediments remained high downstream at least as far as Loon Creek the nitrates disappeared (i.e., they were used up) by the time the water reached the Pine site.

The load, when normalized for drainage area (÷ by km^2), can be used to examine and compare the material yields from the burned and unburned watersheds. Since the watershed yield approach integrates concentration, flow, and drainage area it provides a better means for making comparisons between diverse streams than does load. The most desirable approach is to examine total yield on an annual basis (Likens et al. 1977, Henderson et al. 1978, Gosz 1980). But this requires continuous

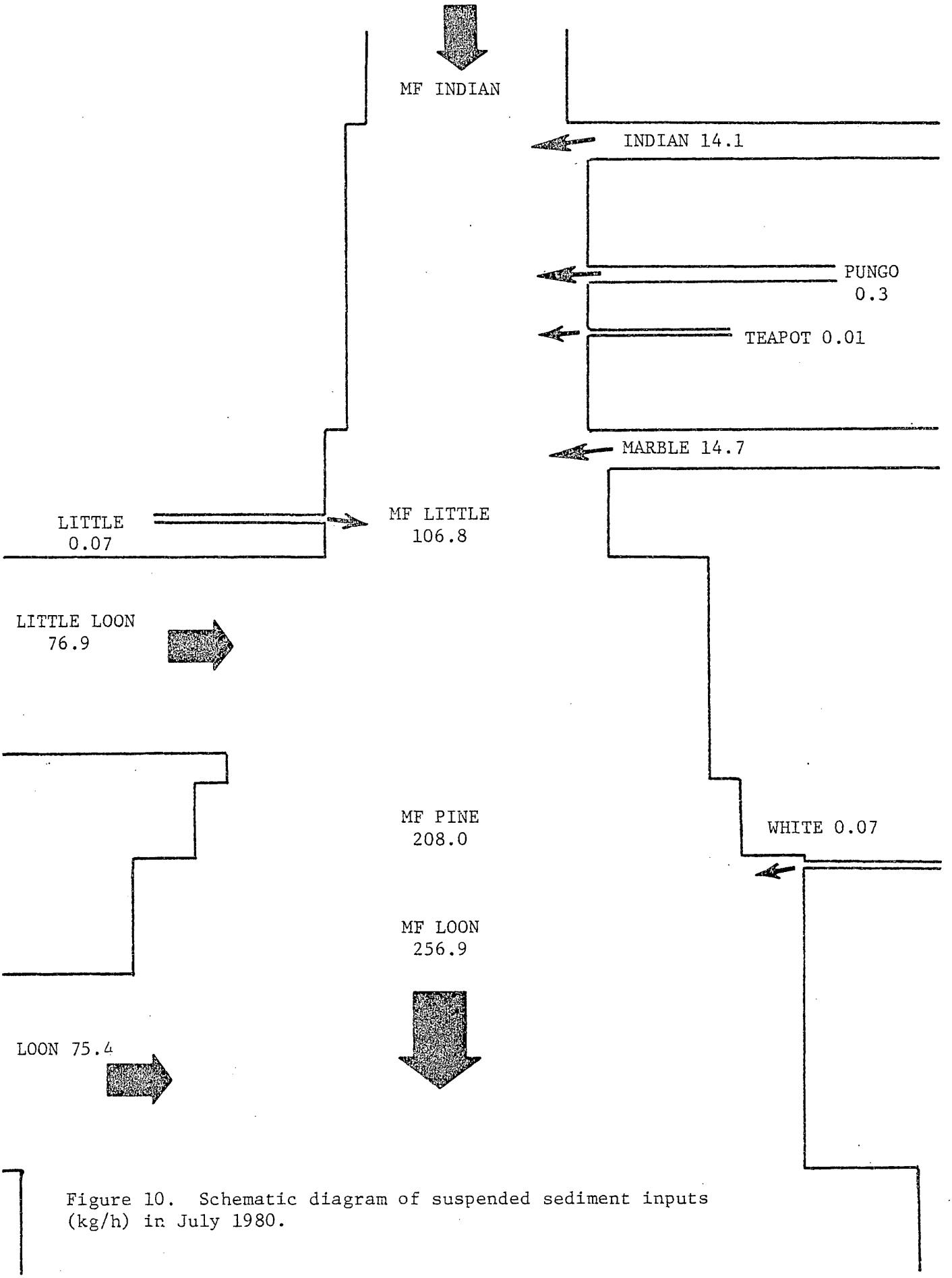
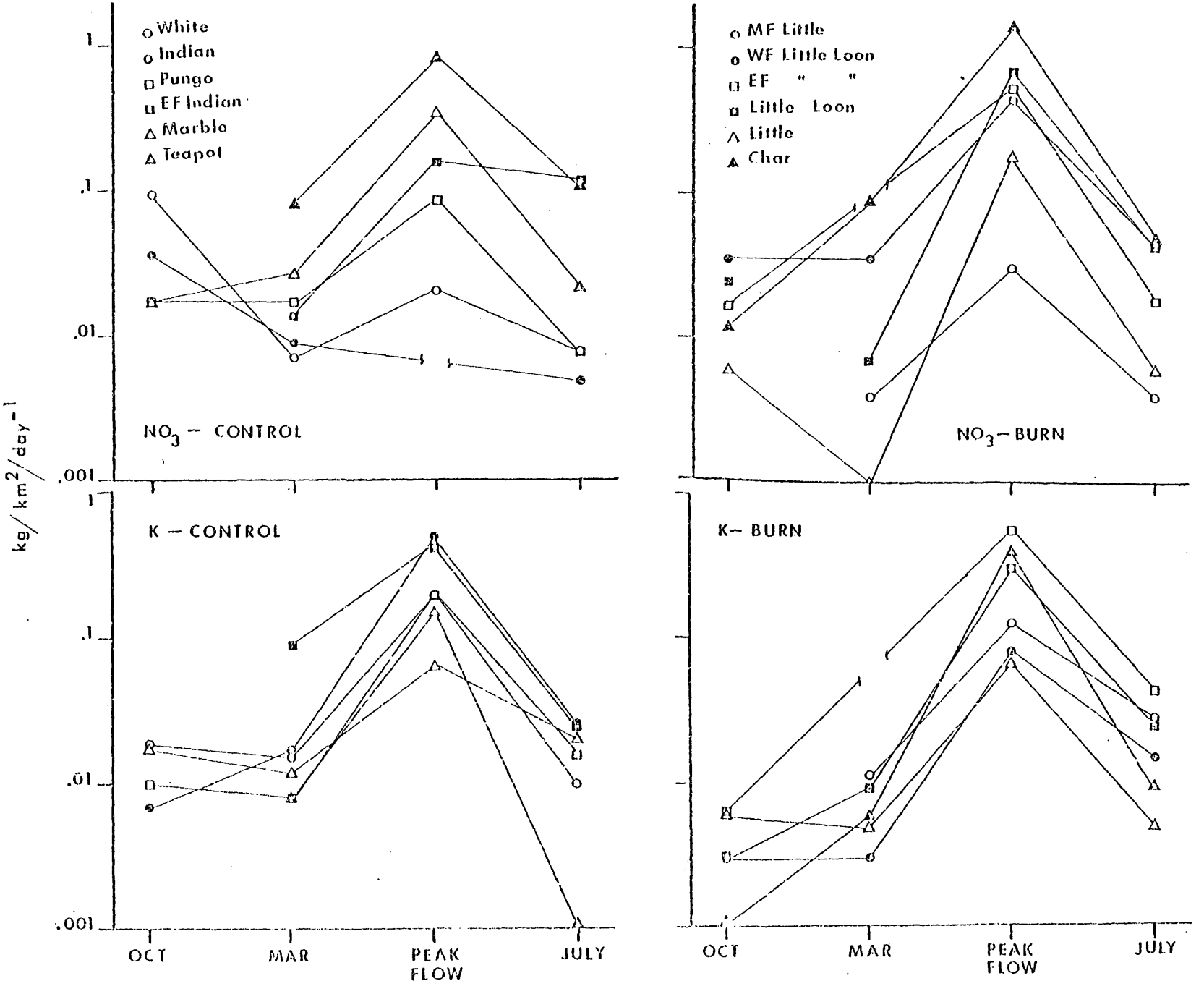


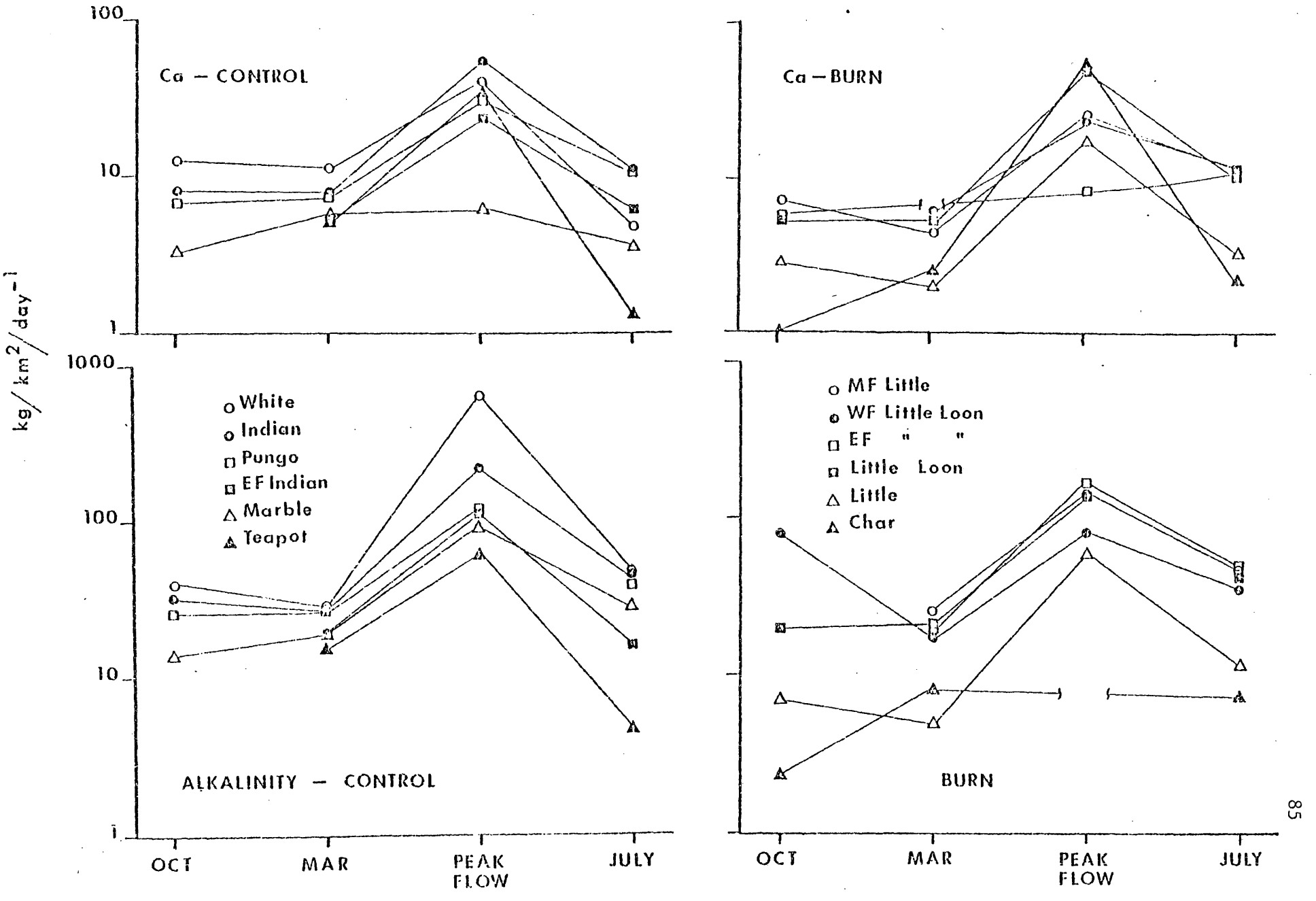
Figure 10. Schematic diagram of suspended sediment inputs (kg/h) in July 1980.

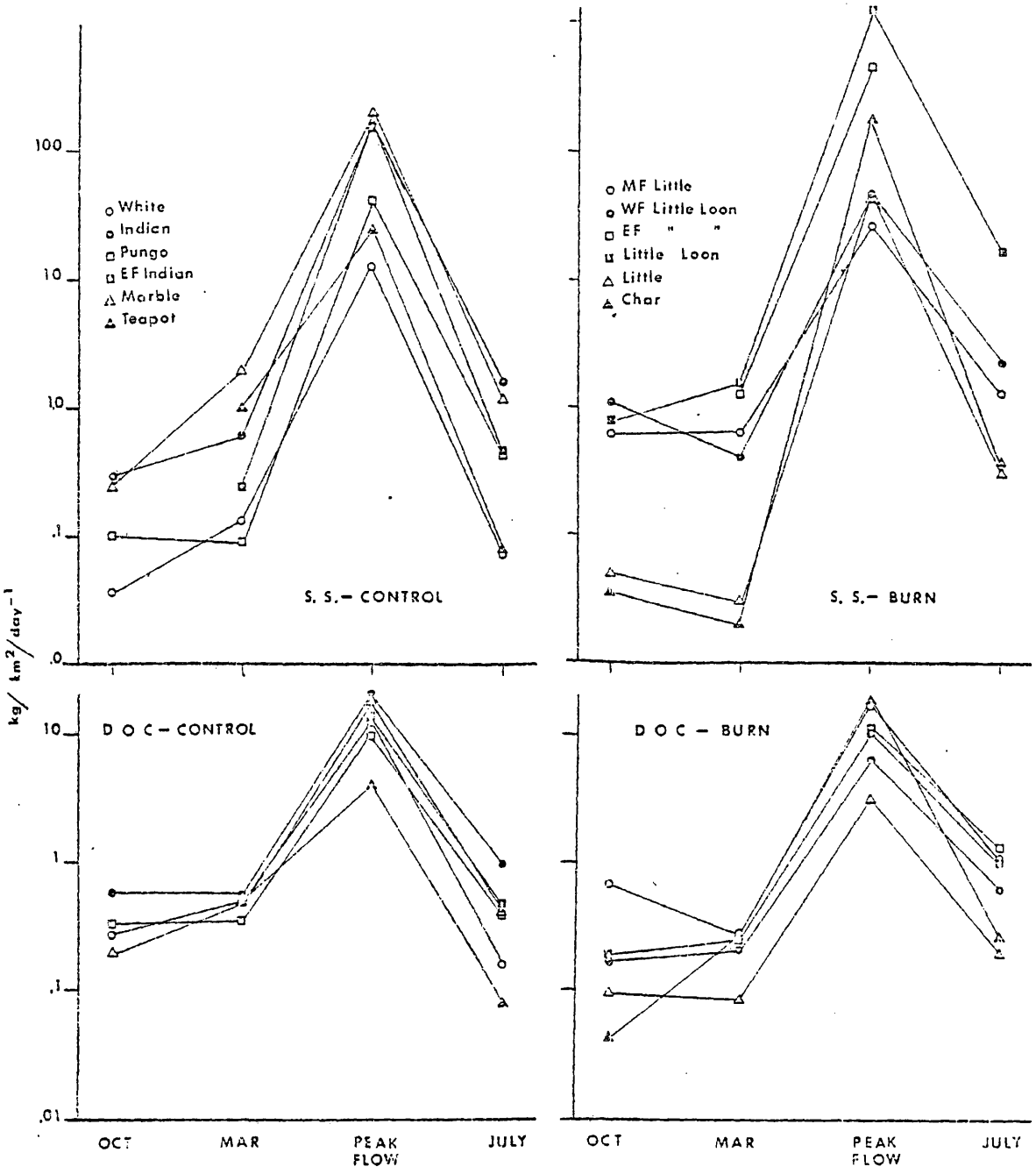
flow measurements, and was not feasible for this study because of the absence of continuously gauged stations, the remoteness of the sites, and inadequate financial support. However, valuable information still can be gained from comparisons of daily yields for different times of the year (Fig. 11).

At base flow, a basin with an appreciably higher yield for a particular material than in adjacent streams will either be "leakier" or have a greater supply of that material. This leads to the expectation that burned watersheds will have greater watershed yields for biologically labile materials (e.g., NO_3 or K) than will unburned watersheds. With respect to nitrate all of the control tributaries (except Teapot which had unusually high concentrations) had yields less than 4 $kg/km^2/ha$ whereas all burn tributaries in the Little Loon drainage exceeded 4. In addition, yield in the burn tributaries varied over three orders of magnitude. Yields of potassium had a wider range in the burn streams than in the controls although the peaks were about the same. On the other hand the winter values were lower in the burn streams. Calcium yields were about the same for burn and control streams. White Creek, however, did not stand out as markedly in regards to calcium yields as it did in terms of concentrations. Yields of DOC varied over three orders of magnitude. In spring, the values for the burn and control streams were virtually identical. But in the summer the levels in the burn streams were slightly higher than in the controls. Suspended sediments in the burn streams ranged from 3-16 $kg/km^2 \cdot da^{-1}$ in July to 25-1200 at peak flow compared to 0.7-1.6 in July and 12-200 at peak flow in the controls. Clearly much more material is coming out of the burned drainages than from the unburned

Figure 11. Watershed yields ($kg/km^2/d$) for selected constituents in burn and control tributaries of the Mortar Creek Fire Study: (a) nitrate and potassium, (b) calcium and alkalinity (as $CaCO_3$), (c) suspended sediments and dissolved organic carbon.


White
Indian
Pungo
EF Indian
Marble
Teapot
NO3 – CONTROL
MF Little
WF Little Loon
EF " "
Little Loon
Little
Char
NO3 – BURN
K – CONTROL
K – BURN
kg/km2/day-1
1
.1
.01
.001
OCT
MAR
PEAK FLOW
JULY


Ca – CONTROL
Ca – BURN
ALKALINITY – CONTROL
BURN
kg/km²/day⁻¹
100
10
1
1000
100
10
1
White
Indian
Pungo
EF Indian
Marble
Teapot
MF Little
WF Little Loon
EF " "
Little Loon
Little
Char
OCT
MAR
PEAK FLOW
JULY


100
10
1.0
.1
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White
Indian
Pungo
EF Indian
Marble
Teapot
S. S.– CONTROL
MF Little
WF Little Loon
EF " "
Little Loon
Little
Char
S. S.– BURN
kg/ km²/day⁻¹
10
1
.1
.01
D O C – CONTROL
D O C – BURN
OCT
MAR
PEAK FLOW
JULY
OCT
MAR
PEAK FLOW
JULY

ones. It will be very informative to see how these yields change over time.

Further insight into differences in transport dynamics between burned and unburned watersheds can be obtained through correlation analysis of the relationship between discharge and concentration of various transported materials. In order to simplify the presentation a dimensionless value for discharge was obtained, following the practice of Emmett (1975), by calculating the ratio of instantaneous discharge (Q) to bankfull discharge (Q_{BKF}). Use of this ratio allows comparison of streams of diverse sizes on a single graph. Since complete (continuous) records of discharge were not available for the study streams from which to determine bankfull discharge we have used instead the peak discharge measured during the sampling trips. In most cases this is a reasonable estimate of bankfull stage.

Previous work (Leopold et al. 1964, Abrahams and Kellerhalls 1973, Brunskill et al. 1975) has shown that concentration varies with discharge according to the power function:

$$\text{Conc.} = a\ Q^{b}$$

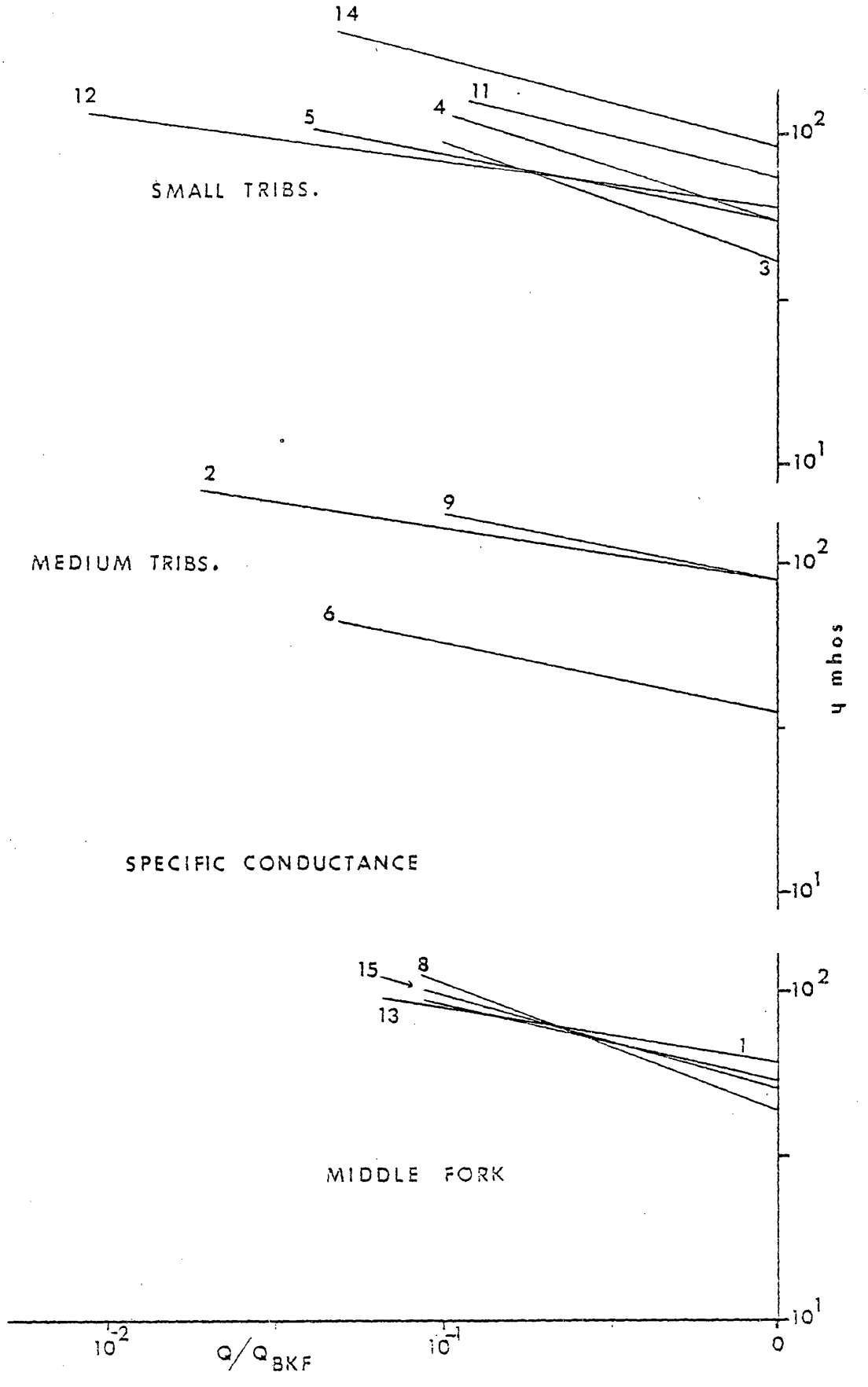
where a is the intercept and b is the slope. In most cases in the present study this relationship yielded the strongest correlations (Table 23) and so it was used in all cases to facilitate comparisons. Log-log transformation of the variables allows the data to be plotted as straight lines. These plots (Fig. 12) show the highest and lowest concentrations for a given Q/Q_{BKF} ratio.

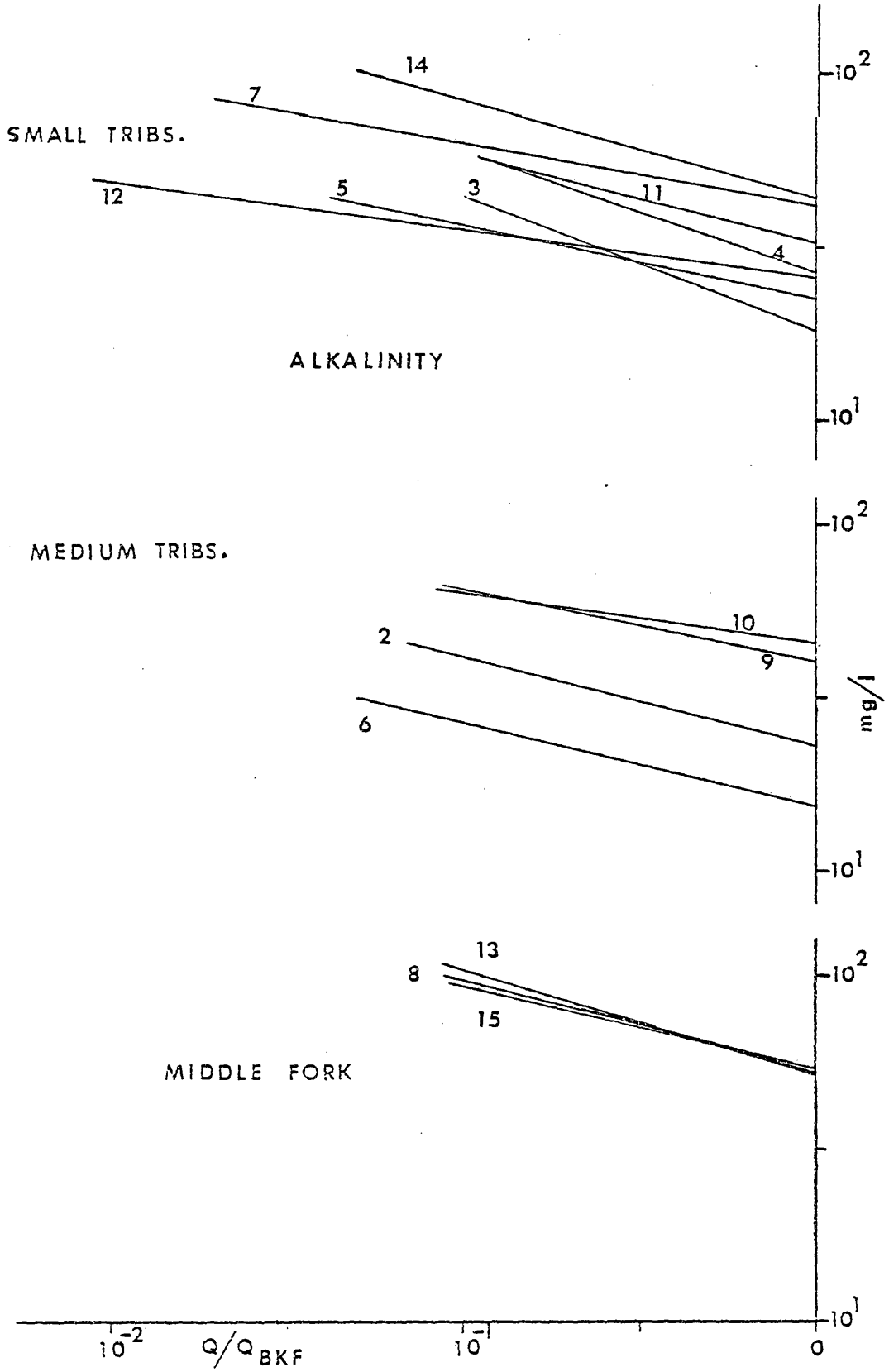
Specific conductance and alkalinity had negative slopes indicating a dilution of ions at the higher discharges. (The steeper the slope the stronger is the diluting effect of runoff.) The small streams had

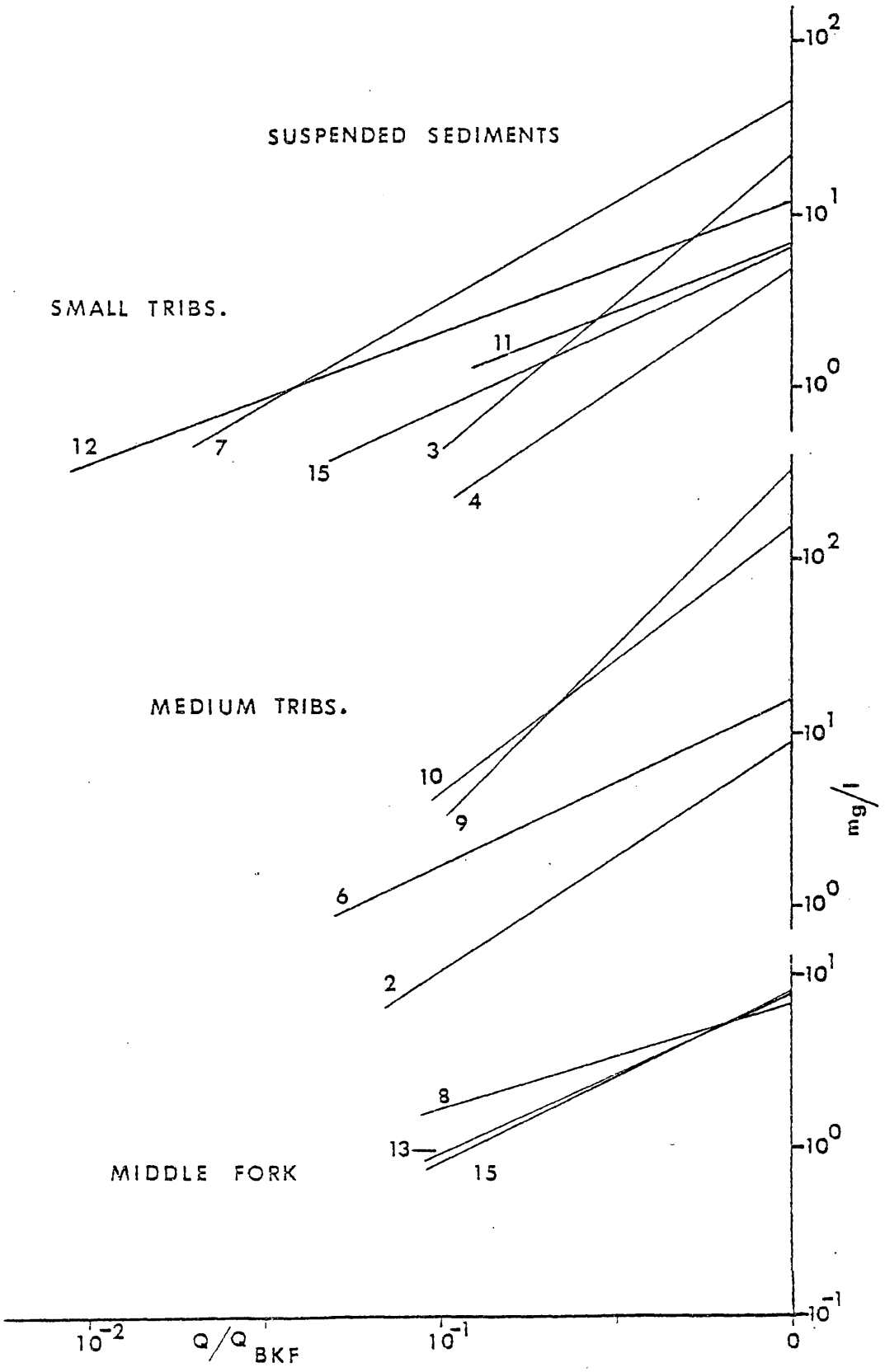
Table 23. Results of regression analysis: discharge (log Q/Q_{BKF}) vs. selected constituents (log concentration) for the Mortar Creek Fire study.

	CONDUCTANCE				ALKALINITY				SUSPENDED SEDIMENT				POM			
Site	r^2	SIG	A	B	r^2	SIG	A	B	r^2	SIG	A	B	r^2	SIG	A	B
MF Indian	0.74	0.048	1.74	-0.22					0.18	0.20			0.17	0.21		
Indian	0.88	0.003	1.70	-0.26	0.93	0.001	1.36	-0.26	0.81	0.01	0.98	1.10	0.87	0.00	0.40	1.01
E. Fk. Indian	0.92	0.00	1.62	-0.36	0.94	0.003	1.26	-0.39	0.94	0.004	1.36	1.76	0.89	0.007	0.71	1.57
Pungo	0.91	0.000	1.74	-0.33	0.97	0.000	1.43	-0.34	0.89	0.001	0.71	1.41	0.72	0.008	0.15	1.16
Teapot	0.71	0.037	1.76	-0.19	0.84	0.014	1.35	-0.22	0.28	0.18			0.05	0.35		
Marble	0.81	0.007	1.55	-0.21	0.90	0.002	1.19	-0.24	0.74	0.014	1.10	0.87	0.74	0.014	0.36	0.88
Little	0.76	0.012	1.95	-0.16	0.67	0.023	1.62	-0.18	0.92	0.001	1.67	1.18	0.87	0.003	1.13	0.84
MF Little	0.84	0.000	1.73	-0.26	0.90	0.000	1.37	-0.27	0.14	0.090	1.01	0.76	0.20	0.065	0.40	0.68
L. Loon	0.60	0.012	1.95	-0.20	0.79	0.002	1.61	-0.21	0.97	0.000	2.54	2.07	0.94	0.000	1.57	1.63
E. Fk. L. Loon	0.36*	0.142			0.61	0.060	1.66	-0.15	0.75	0.029	2.27	1.38	0.96	0.010	1.20	1.12
W. Fk. L. Loon	0.95	0.001	1.87	-0.25	0.98	0.000	1.52	-0.25	0.55	0.045	0.84	0.69	0.49	0.061	0.45	0.54
Char	0.97	0.001	1.78	-0.14	0.97	0.001	1.41	-0.14	0.60	0.035	1.09	0.82	0.39	0.092	0.57	0.78
MF Pine	0.96	0.002	1.71	-0.29	0.98	0.000	1.37	-0.26	0.74	0.013	0.94	0.94	0.69	0.021	0.35	0.76
White	0.77	0.011	1.97	-0.27	0.85	0.004	1.64	-0.28	0.80	0.008	0.92	1.03	0.70	0.020	0.45	0.89
MF Loon	0.84	0.005	1.73	-0.24	0.91	0.002	1.39	-0.25	0.78	0.004	0.94	0.97	0.83	0.002	0.45	0.91

Figure 12. Relationship between discharge (expressed as the ratio of Q to Q_{BKF}) and selected constituents: (a) specific conductance, (b) alkalinity, (c) suspended sediments, and (d) particulate organic matter for the Mortar Creek Fire sites: 1. MF Indian, 2. Indian, 3. E. Fk. Indian, 4. Pungo, 5. Teapot, 6. Marble, 7. Little, 8. MF Little, 9. L. Loon, 10. E. Fk. L. Loon, 11. W. Fk. L. Loon, 12. Char, 13. MF Pine, 14. White, 15. MF Loon.


14
12
11
4
5
3
SMALL TRIBS.
10^2
10^1
2
9
MEDIUM TRIBS.
6
10^2
10^1
μ mhos
SPECIFIC CONDUCTANCE
15
8
13
1
MIDDLE FORK
10^2
10^1
10^{-2}
Q/Q_{BKF}
10^{-1}
0


SMALL TRIBS.
14
7
12
5
3
11
4
ALKALINITY
10^2
10^1
MEDIUM TRIBS.
10
2
9
6
mg/l
10^2
10^1
13
8
15
MIDDLE FORK
10^2
10^1
10^{-2}
Q/Q_{BKF}
10^{-1}
0


SUSPENDED SEDIMENTS
SMALL TRIBS.
MEDIUM TRIBS.
MIDDLE FORK
12
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10
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2
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10^2
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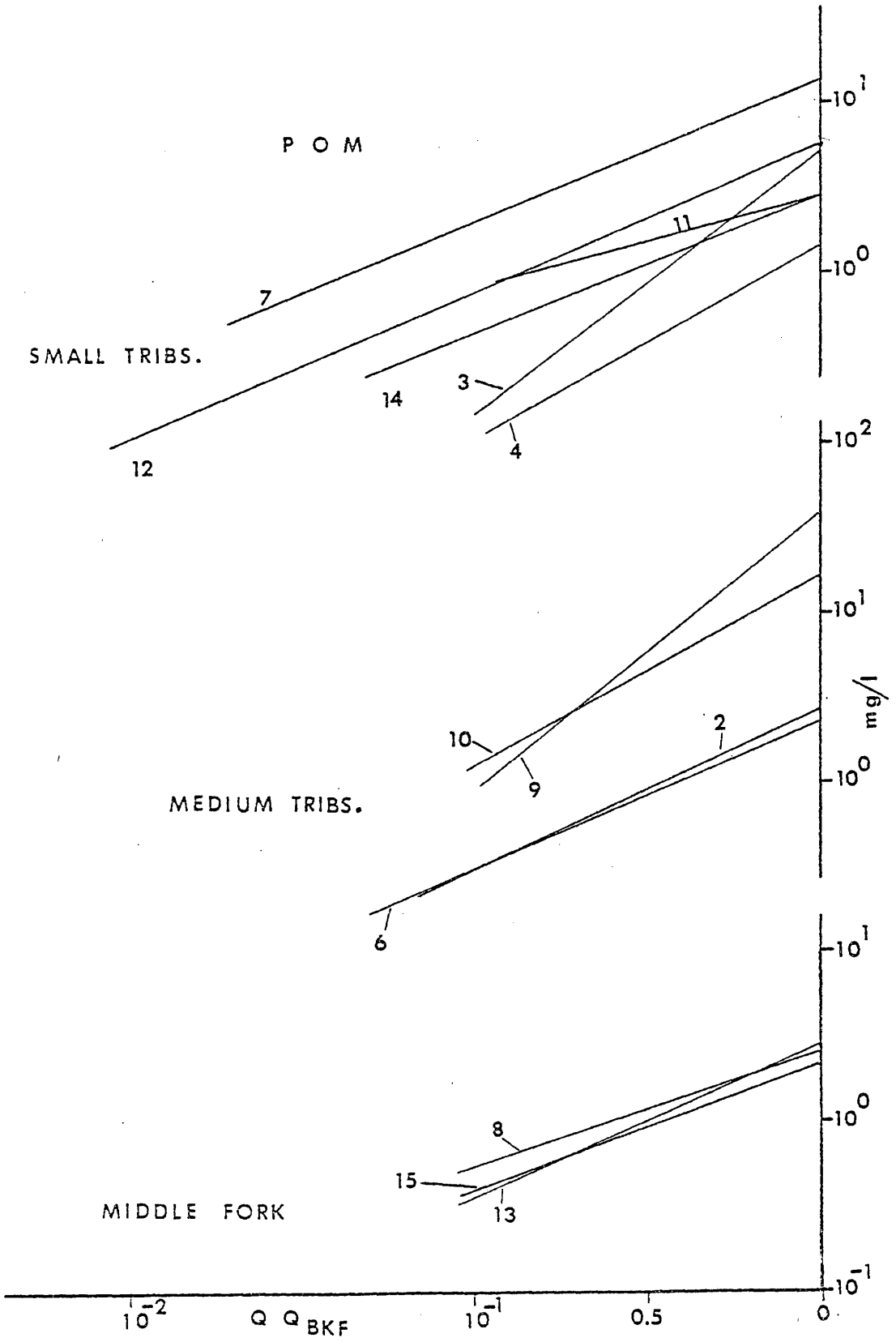
mg/l
10^{-2}
Q/Q_{BKF}
10^{-1}
0


P O M
SMALL TRIBS.
MEDIUM TRIBS.
MIDDLE FORK
7
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10^{-1}
mg/l
10^{-2}
Q Q_{BKF}
10^{-1}
0.5
0

a broader range of Q/Q_{BKF} values than did the others. Slopes of specific conductance for all sites generally were similar although Marble had the lowest values at any flow and White Creek the highest. In regard to alkalinity, the small tributaries had a broad range reflecting the geologic heterogeneity of the drainages. Values for White Creek were distinctly higher at all flows although they were approached by those of Little Creek during peak discharge. The three small control streams had the steepest slopes ($b \geq 0.28$). In the medium tributaries alkalinity was distinctly higher at Little Loon than at either Marble or Indian Creeks. All of the sites in the main river were nearly identical and the values were higher than most of the tributaries under all flow conditions.

Suspended sediments and particulate organic matter (POM) showed a general increase in concentration with an increase in discharge (Fig. 12). On the main river, slopes of suspended sediments for the sites below Little Loon Creek were greater than those above. The Little Loon drainage had dramatically greater slopes and higher intercepts for suspended solids than any of the other streams. In the small tributaries, the intercepts of the controls generally were lower than those of the burn streams. An exception was the East Fork of Indian Creek which was sampled on what appeared to be a particularly active time of snowmelt. The slopes for suspended sediments in the small tributaries were quite variable between burned and control watersheds so that no distinct differences emerge. The slopes for particulate organic matter generally were lower than those for suspended sediments but otherwise the two showed the same trends.

The intercept (a) values are an index to the susceptibility of the drainage systems to the erosion of materials whereas the slopes indicate the energy of the streams to transport material (Brunskill et al. 1975, Brock 1980). In the present study the burn streams had 4 of the 5 highest a's for suspended matter and 5 of the 6 highest for POM. This analysis indicates that in general the Mortar Creek Fire has increased the erodability of the affected watersheds for suspended inorganic and particulate organic material. This approach may be one of the most valuable means available for assessing the impact of disturbance and rates of recovery of perturbed watersheds. We expect the suspended sediment and POM intercepts to decrease as the burned watersheds recover whereas the control streams should remain constant. Subsequent periodic measurement of these values over an extended period of time would provide a valuable test of these ideas and establish an index to rate of watershed recovery in the Intermountain Region.

Flow is a dominant force controlling nutrient and sediment concentration and yield in streams of the Middle Fork of the Salmon River. Specific conductance and concentration of major ions vary indirectly with discharge level. While flow serves to dilute or concentrate ions which leave a watershed, precipitation and bedrock type are major factors controlling the source of dissolved material. Precipitation chemistry was not quantified in this study, but probably is not highly variable between proximate drainages. On the other hand, geologic mapping reveals the heterogeneity of bedrock type in the portion of Central Idaho drained by the Salmon's Middle Fork. We found specific conductance to be highly correlated with most of the major ions in

Middle Fork drainage. Thus, conductivity provides a method by which the variability of bedrock influence on stream water chemistry may be inferred. Specific conductance was determined on 50 Middle Fork tributaries during July-August 1980 in order to delimit the variability in ionic strength of different-sized streams draining diverse bedrock types. When feasible, pH also was determined for these grab samples. The results of this synoptic sample series reveal the wide range in conductances within streams of each order (Table 24). Variation (expressed as CV) ranged from 33-47% for orders 1-5. Samples from the three major 6th order tributaries (Camas, Loon, and Big Creek had remarkably similar conductances ($\bar{x}$ = 96.9; CV = 4%). Conductance for most study tributaries, both burn and control, fell within the range of values for streams of like order. Little Loon and White Creek had the highest values for their respective stream orders. White Creek had one of the highest conductances, ranking 7th out of the 50 streams. These data illustrate the difficulties inherent in comparison of water chemistry between streams of different drainages in regions with diverse geologic substrata. As previously stated, it is highly desirable to monitor the recovery of fire-impacted streams as their watersheds recover over the years. Conclusions based on observations contrasting chemistry in burn vs. control areas are not definitive since each drainage is unique. Optimally, both control and impacted streams would be monitored from year to year to allow identification of annual variance within a control stream. The summer specific conductance sample series provided an idea of the overall effect of the Mortar Creek Fire on total dissolved solids along the main river (Fig. 13 . Specific conductance of the main river increased gradually along the 155 km

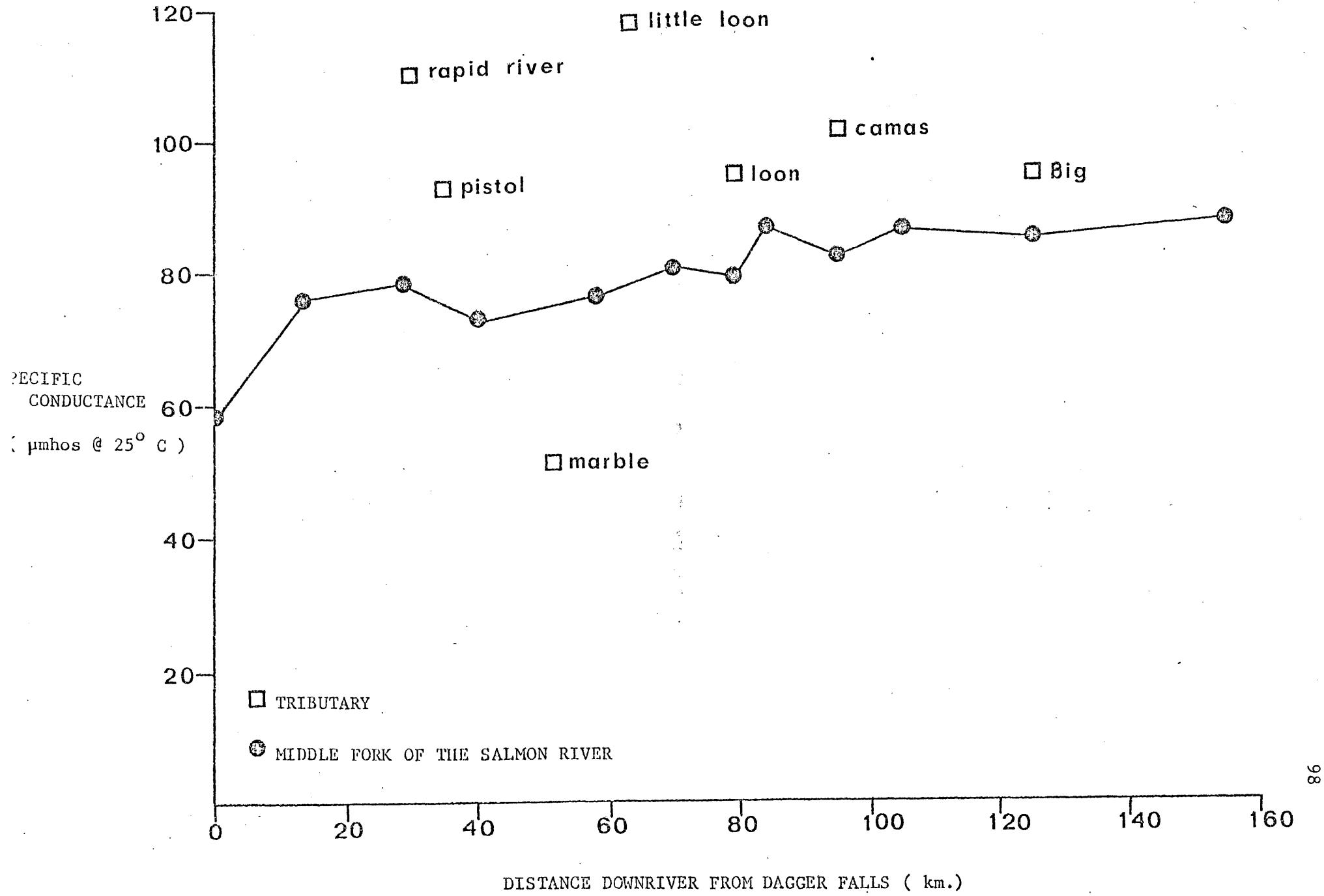
Table 24. Specific conductance and pH of Middle Fork Salmon streams during summer 1980 by stream order and link magnitude. B = burn sites; C = control sites; primary study sites for the Mortar Creek Fire study are underlined. Number in parentheses is standard deviation.

ORDER	LINK	SITE	DATE	pH	CONDUCTANCE
1	1	Teapot (C)	21/7		92.6
	1	Dome (C)	21/7		73.7
	1	Chutes (C)	21/7		113.1
	1	Cold Spring/Ramshorn (C)	21/7		32.8
	1	Waterfall Ck. Spring (C)	1/8	7.69	60.0
	1	Burnt Tree (B)	2/8	7.95	98.5
					$\bar{X}$ =78.4 (29.2)
2	2	Lake (C)	21/7	7.58	50.3
	2	Char (B)	27/7	8.03	94.6
	2	Shep (C)	28/7	7.40	202.0
	2	Bacon (C)	28/7	8.20	223.0
	2	Rattlesnake (C)	21/7	7.90	139.6
	3	Artillery (C)	1/8		84.3
	4	Ramshorn (C)	21/7	7.65	45.3
	4	Culver (C)	28/7	8.00	128.5
	4	Red Bluff (C)	28/7	8.03	105.6
	6	Tumble (B)	2/8	7.88	91.6
	7	Little (B)	25/7		143.0
	7	Cold Spring (C)	31/7	8.07	139.3
	10	Pungo (C)	24/7		108.9
					$\bar{X}$=119.7 (51.8)
3	4	Grouse (C)	30/7	8.18	68.0
	6	Nugget (C)	2/8	7.98	150.2
	6	Greyhound (B)	21/7	7.63	119.4
	7	Little Aparejo (C)	30/7	8.03	172.5
	11	Parrott (B)	2/8	7.89	70.5
	12	E. Fk. Indian (C)	23/7	8.23	95.5
	12	Big Bear (C)	31/7	8.22	171.8
	13	Pine (C)	28/7	8.03	180.0
	13	Aparejo (C)	30/7	8.05	186.3
	20	Goat (C)	2/8	7.89	56.1
	22	Jack (C)	31/7	7.97	94.7
	23	Ship Island (B)	1/8		27.4
					$\bar{X}$=116.0 (55.0)
4	19	Elkhorn (C)	21/7		106.6
	21	Waterfall (C)	1/8	7.69	43.5
	24	White (C)	28/7	8.22	168.1
	24	W. Fk. Little Loon (B)	27/8	8.18	102.4
	30	Stoddard (C)	2/8	7.65	63.4

Table 24, continued.

ORDER	LINK	SITE	DATE	pH	CONDUCTANCE	
	34	Sulfur (C)	21/7	7.56	58.8	
	41	Soldier (C)	21/7	8.02	81.5	
	47	Norton (C)	30/7	7.93	115.4	
	52	Sheep (C)	31/7	8.03	120.4	
	89	Indian (C)	23/7		77.2	
	92	Wilson (C)	1/8	8.05	66.4	
	105	E. Fk. Little Loon (B)	27/7	8.18	119.5	
					$\bar{X}$= 93.6	(35.0)
5	93	Pistol (C)	22/7		87.9	
	132	Little Loon (B)	26/7	8.10	117.8	
	249	Rapid River (B)	22/7		110.3	
	262	Marble (C)	25/7		51.1	
					$\bar{X}$= 91.8	(29.9)
6	825	Camas (C)	30/7	8.03	101.3	
	903	Loon (C)	29/7		94.5	
	940	Big (C)	1/8	8.41	94.9	
					$\bar{X}$= 96.9	(3.8)
Middle Fork						
6	559	Dagger (C)	20/7	7.94	58.8	
6	656	Chutes (C)	20/7	8.47	76.1	
6	767	Artillery (C)	20/7		78.8	
6	1218	Indian (C)	22/7	8.04	73.0	
6	1608	Little (C)	25/7		76.6	
6	1817	Pine (B)	28/7	8.07	80.8	
6	1887	Loon (B)	29/7	8.16	79.4	
7	2845	Hospital (C)	30/7	7.98	86.3	
7	2924	Camas (C)	31/7	7.97	82.9	
7	3853	Sheep (C)	1/8	8.18	86.5	
7	4193	Big (C)	1/8	8.40	85.1	
7	5412	Mouth (B)	2/8	8.17	87.8	
8	6721	Main Salmon Above MF (C)	2/8	8.68	240.0	
8	12,235	Main Salmon below MF @ Cache Bar (C)	2/8	8.65	166.5	

Figure 13. Specific conductance of Middle Fork along a longitudinal sample series collected 20 July - 2 August 1980. Conductances of 5th and 6th Order tributaries also are indicated.


120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
little loon
rapid river
camas
pistol
loon
Big
marble
TRIBUTARY
MIDDLE FORK OF THE SALMON RIVER
PECIFIC
CONDUCTANCE
(µmhos @ 25° C)
DISTANCE DOWNRIVER FROM DAGGER FALLS (km.)

transect. Although Little Loon had the highest conductance of the seven 5th and 6th order tributaries, it did not appreciably increase conductance in the main river.

Composition of Transported Organic Matter

Amounts and relative abundances by size fraction of the transported organic matter are given in Table 25. Concentrations of fine particulate matter in transport usually ranged from 0.08 to 0.57 mg/l in the small control streams. Values for the small burn sites overlapped those of the controls but in the case of Char Creek went much higher (overall range 0.09 to 4.6). Levels of fine seston in Little Creek and West Fork of Little Loon were intermediate compared to the other streams. Compared to the small control streams, the medium and large controls generally transported low concentrations of fine materials in the summer. Values for coarse material were highly variable. This probably is primarily a sampling problem since the particles are relatively rare but when captured contribute a fairly large amount to the sample. Concentrations generally were low and those of the controls overlapped those of the burn streams. However, in the small tributaries there generally was twice as much coarse material in transport at the burn sites as at the control sites. For the medium-sized streams, Little Loon Creek had high values in Fall 1979 as a result of elevated inputs from the fire. But in summer, because of removal of retention devices, coarse transport concentrations remained exceedingly high (0.70 g/m^3). The dramatic differences between coarse and fine transport characteristics in Little Loon Creek and the medium control tributaries are depicted in Fig. 14. Pre-runoff (Fall 1979) fine organic transport concentration for Little Loon are 2-4 times Indian

Table 25. Characterization of transported particulate organic matter by particle size for the Mortar Creek Fire study sites. Dry weights and ash-free dry weights (AFDW) are in g/m^3.

Site	Date	FINE Dry	FINE AFDW	FINE % Organic	COARSE Dry	COARSE AFDW	COARSE % Organic	% ULTRA-FINE	% FINE	% COARSE	C/F	C/U+F
Teapot (C)	240780	0.193	0.093	48.4	0.031	0.026	83.8	87.6	9.7	2.7	0.276	0.028
Char (B)	301079	0.155	0.088	56.8	0.016	0.011	66.4	93.1	6.2	0.7	0.120	0.008
	250480	22.140	4.635	20.9	7.996	3.604	45.1	30.2	39.3	30.5	0.778	0.440
	140580	2.056	0.690	33.6	0.259	0.207	80.0	97.7	1.8	0.5	0.300	0.005
	200580	0.266	0.079	29.8	0.800	0.346	43.2	86.3	2.6	11.2	4.36	0.126
	270780	0.314	0.122	38.8	0.064	0.023	35.1	86.5	11.4	2.1	0.186	0.022
Pungo (C)	281079	0.121	0.076	62.5	0.015	0.014	89.9	87.1	11.0	2.0	0.179	0.020
	230480	4.486	0.574	12.8	1.149	0.425	36.9	63.8	20.8	15.4	0.740	0.182
	120580	1.229	0.339	27.6	0.170	0.124	72.6	67.5	23:8	8.7	0.364	0.095
	170580	0.653	0.233	35.6	0.103	0.076	73.6	18.0	61.9	20.2	0.326	0.253
	230780	0.751	0.394	52.5	0.063	0.056	88.6	--	--	--	0.141	--
Little (B)	291079	0.711	0.477	67.1	0.009	0.008	84.9	73.5	26.1	0.4	0.016	0.004
	200480	3.531	1.311	37.1	38.706	4.525	11.7	8.4	20.6	71.0	3.452	2.454
	240480	8.969	1.317	14.7	16.442	14.238	86.6	72.5	2.3	25.1	10.812	0.336
	130580	3.166	1.250	39.4	0.465	0.468	100.0	66.8	24.1	9.1	0.376	0.100
	180580	1.714	0.699	40.8	0.367	0.313	85.2	66.8	22.9	10.3	0.448	0.114
	180580	1.980	0.848	42.8	0.330	0.250	75.6	45.1	42.5	12.5	0.294	0.142
	190580	2.425	0.950	39.2	0.650	0.501	77.1	--	--	36.2	0.527	0.566
	190580	4.022	1.518	37.7	0.903	0.757	83.9	32.5	45.0	22.5	0.500	0.290
E. Fk. Indian (C)	220480	15.388	4.156	27.0	3.431	2.147	62.6	56.7	28.5	14.7	0.516	0.173
	120580	1.634	0.455	27.9	0.195	0.144	73.6	29.0	54.0	17.0	0.316	0.205
	170580	0.274	0.118	43.0	0.068	0.057	83.9	83.4	11.2	5.4	0.484	0.057
	230780	0.259	0.118	45.7	0.008	0.058	75.4	85.6	9.7	4.8	0.493	0.050
	230780	0.232	0.115	49.6	0.032	0.028	85.9	87.9	9.8	2.3	0.239	0.024

Table 25, continued.

Site	Date	FINE Dry	FINE AFDW	FINE % Organic	COARSE Dry	COARSE AFDW	COARSE % Organic	% ULTRA-FINE	% FINE	% COARSE	C/F	C/U+F
White (C)	011180	0.244	0.159	65.3	0.012	0.010	83.1	60.9	36.8	2.3	0.064	0.024
	150580	1.232	0.572	46.4	0.138	0.111	80.9	87.1	10.8	2.1	0.194	0.021
	200580	0.669	0.343	51.3	0.188	0.135	71.6	70.8	21.0	8.2	0.393	0.090
	280780							66.2	31.8	2.1	0.065	0.021
W. Fk. Little Loon (B)	301079	0.367	0.245	66.8	0.049	0.042	86.4	89.7	8.8	1.5	0.172	0.015
	250480	6.191	1.995	32.2	1.506	1.140	75.7	59.5	25.8	14.7	0.571	0.173
	140580	2.315	0.999	43.1	0.506	0.430	84.9	77.8	15.5	6.7	0.430	0.072
	200580	2.121	0.731	34.5	0.494	0.398	80.6	67.2	21.2	11.6	0.545	0.131
	270780	1.525	0.676	44.3	0.342	0.221	64.7	46.3	40.5	13.2	0.327	0.153
Indian (C)	271079	0.122	0.049	40.0	0.008	0.007	79.1	94.8	4.6	0.6	0.138	0.006
	220480	5.702	0.656	11.5	4.526	0.887	19.6	76.1	10.2	13.8	1.353	0.160
	120580	1.892	0.216	11.4	0.414	0.139	33.6	86.0	8.5	5.5	0.644	0.058
	170580	0.885	0.066	7.5	0.117	0.061	52.7	92.8	3.8	3.5	0.928	0.036
	230780	0.234	0.086	36.7	0.014	0.012	86.9	84.8	13.3	1.9	0.139	0.019
Marble (C)	281079	0.136	0.064	46.9	0.0018	0.0025	73.2	92.3	7.5	0.2	0.029	0.002
	230480	26.260	0.897	3.4	3.747	0.457	12.2	84.9	10.0	5.1	0.510	0.054
	120580	9.317	0.451	4.8	0.248	0.172	69.4	77.5	16.3	6.2	0.381	0.066
	170580	4.166	0.264	6.3	0.388	0.145	37.4	45.1	35.4	19.5	0.550	0.242
	250780	0.206	0.067	32.6	0.027	0.006	21.7					
Little Loon (B)	301079	0.262	0.133	50.6	0.213	0.195	91.3	80.7	7.8	11.5	1.467	0.130
	240480	647.465	32.807	5.1	67.860	14.677	21.6	--	--	33.8	0.447	0.506
	140580	173.803	3.846	2.2	31.799	0.958	3.0	70.3	23.8	5.9	0.249	0.063
	140580	266.529	6.184	2.3	65.177	2.683	4.1	38.2	43.1	18.7	0.434	0.230
	150580	228.580	4.860	2.1	42.168	0.962	2.3	--	--	40.2	0.198	0.672
	190580	55.706	1.588	2.9	4.060	0.436	10.7	57.5	33.3	9.1	0.274	0.101
	190580	68.733	2.148	3.1	3.799	0.463	12.2	63.2	30.3	6.5	0.215	0.070
	200580	53.558	1.871	3.5	3.389	0.306	9.0					
	260780	47.362	0.915	1.9	39.788	0.697	1.8	--	--	--	0.762	--

Table 25, continued.

Site	Date	FINE Dry	FINE AFDW	FINE % Organic	COARSE Dry	COARSE AFDW	COARSE % Organic	% ULTRA-FINE	% FINE	% COARSE	C/F	C/U+F
Loon (C)	021179	0.205	0.093	45.4	1.582	1.435	90.7	48.0	3.2	48.9	15.419	0.956
	160580	9.285	0.371	4.0	0.480	0.086	17.9	91.0	7.3	1.7	0.231	0.017
	290780	0.646	0.349	54.0	0.045	0.016	36.1	96.2	3.5	0.3	0.088	0.003
Big (C)	041179	0.283	0.117	41.4	0.076	0.003	3.7	87.0	12.7	0.3	0.024	0.003
	010880	0.541	0.189	34.9	0.015	0.012	74.9	67.3	30.9	1.9	0.061	0.091
MF Dagger (C)	171079	0.169	0.117	69.4	0.0037	0.0021	55.7	90.2	9.6	0.2	0.018	0.002
	200780	0.316	0.147	46.6	0.015	0.008	58.0	91.8	7.7	0.4	0.058	0.004
MF Above Indian (B)	271079	0.279	0.143	51.1	0.016	0.002	13.1	87.5	12.3	0.2	0.015	0.002
	210480	3.718	1.063	28.6	0.284	0.227	80.1	90.6	7.7	1.7	0.214	0.017
	220480	4.001	1.192	29.8	0.201	0.147	73.1	73.8	23.3	2.9	0.123	0.030
	110580	5.115	0.690	13.5	0.157	0.132	84.3	61.5	32.3	6.2	0.192	0.066
	160580	1.242	0.194	15.7	0.096	0.065	67.4	70.4	22.2	7.4	0.334	0.080
MF at Little (B)	291079	0.242	0.130	53.7	0.0013	0.0009	74.3	89.3	10.6	0.1	0.007	0.001
	200480	5.684	1.318	23.2	1.314	0.170	12.9	--	--		0.129	
	240480	32.003	10.792	33.7	0.276	0.232	84.1			2.4	0.022	0.024
	130580	7.896	0.419	5.3	0.889	0.230	25.9	83.0	10.9	6.0	0.550	0.064
	180580	3.536	0.342	9.7	0.088	0.057	65.2	82.5	15.0	2.5	0.168	0.026
	180580	2.398	0.294	12.3	0.284	0.066	23.2					
	190580	3.196	0.346	10.8	0.188	0.071	37.9					
	190580	4.747	0.392	8.2	0.576	0.132	23.0					
	250780	0.261	0.117	45.0	0.009	0.008	83.7	71.6	26.6	1.8	0.066	0.018
MF at Pine Ck Flat	11180	0.180	0.093	51.8	0.0010	0.0005	47.1	88.1	11.8	0.1	0.005	0.001
	150580	4.766	0.473	9.9	0.256	0.151	59.0	83.9	12.2	3.9	0.319	0.040
	200580	8.772	0.708	8.1	0.253	0.139	55.0	73.0	22.6	4.4	0.196	0.046
	280780				0.007	0.006	80.4					
MF above Loon Ck	021179	0.200	0.092	46.1	0.0006	0.0004	58.7	86.9	13.0	0.1	0.004	0.0001
	290780	0.311	0.129	41.4	0.0033	0.0029	88.3	35.4	63.2	1.4	0.023	0.015

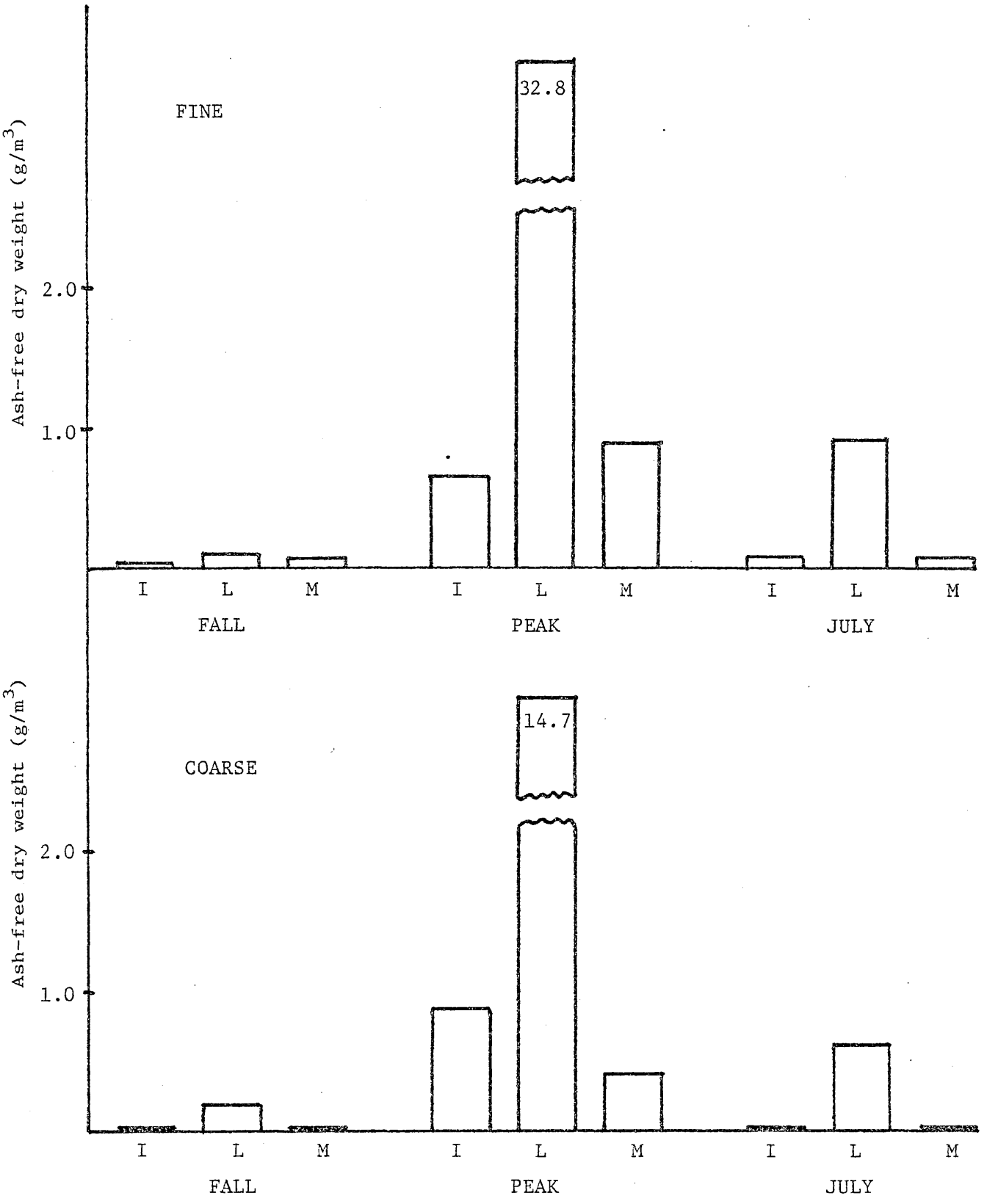


Fig. 14. Transported organic material concentrations in Indian (I), Little Loon (L), and Marble (M) Creeks during Mortar Creek Fire Study. Plotted concentrations (g/m^3) are for samples collected in Fall (October 1979), Peak (maximum concentration during runoff; April-May 1980), and July (1980).

and Marble Creek values, whereas Little Loon is 37 times higher than Marble during peak-measured runoff and 11 times higher than Indian during summer. A similar pattern holds when coarse transport at Little Loon is compared to the control streams (Fig. 14). The heavy particulate organic output from Little Loon which began during spring runoff and was restimulated by the June thunderstorm continued through to the summer. The massive export of particulate material from Little Loon drainage can be considered a direct result of the severe disturbance caused by the Mortar Creek Fire.

In the small control tributaries, the organic fraction (%) (Table 25) generally was high throughout the year. Values during base flow ranged from 75 to 90% and only dipped to 60 to 75% during runoff. These data indirectly indicate that there is comparatively little inorganic movement in these small, unburned watersheds. In the small burn tributaries, the percent coarse organic matter was high during base flow but in several cases decreased markedly during runoff. For example, the value for Char was reduced to 43% and only 12% of the coarse transport at Little Creek was organic. Coarse organic matter in the medium-sized control tributaries showed a greater seasonal variation than the small streams, ranging from 12 to 91% organic. However, except for a high pre-runoff value (91%) Little Loon Creek coarse transport was consistently low in organic content (<25%) and during the May runoff period dropped to 5%. The very low levels present in the summer (1.8%) indicate that most of the organic material had been swept away by this time. With the absence of any major source of resupply of coarse organic material in this watershed, the values are likely to remain low for some time to come. This will have a

very dramatic detrimental effect on the shredder functional feeding component of the invertebrate community.

The composition of fine materials in transport in the small tributaries was highly variable whether the watershed had been burned or not (range ca. 10 to 70% organic). But the values were consistently greater than 40% organic during base flow, indicating a reliable source of supply. The medium-sized control tributaries had a considerably lower percentage of organic matter in the fine fraction than did the small streams (range 4-54%). Like in the small tributaries, the lowest values for the intermediate streams occurred during high discharge. During base flows the values were between 30 and 40% organic. Little Loon Creek provided a dramatic contrast to conditions found in the control streams. There, all of the samples except the pre-runoff one contained only 5% organic matter or less. As with Little Creek, the values in Little Loon during the summer were <2% indicating the virtual elimination of stored fine organic matter from the stream.

There were no obvious differences in the percent organic matter of the fine fraction at the different locations in the main river. However, the levels for the coarse material appear to have increased at Pine (range 47-80%) compared to those found upstream (range 13-84%). This probably reflects the increased loading of materials from Little Loon Creek and the differential settling out of the inorganic particles between the two sampling locations.

Since all stream organic material is suspended at some time in the water column, information on the qualitative composition of seston serves as an indicator of upstream ecological conditions. Seston food quality also can be an important determinant of faunal distribution

especially for filter feeding invertebrates. Three indices of transported matter quality were utilized in this study: percentage organic, chlorophyll a content, and carbon/nitrogen content.

Most of the material in transport consists of ultra-fine and fine particles termed suspended sediments in Table 19 which also presents data on the percent that is organic. For most streams there was a significant inverse correlation between the fraction of the seston that is organic and flow (Table 21). The small tributaries, whether burn or control, generally carried material that was in excess of 50% organic matter except during peak flow periods when it might drop to 35%. The medium control tributaries and the main river transported substantially lower percentages of organic matter than the small streams. Values in these streams commonly were less than 50% but more than 15%. Little Loon Creek had the lowest values of all, ranging from 9-16% during runoff. Summer levels were only 19% compared to 41 and 51% for Marble and Indian Creeks, respectively. The low percent organic values indicate poor food quality for filter feeders. Filter feeders may even be limited in the Middle Fork downstream from Little Loon until the latter clears up not only because of the dilution of food quality but also through the clogging of their collecting nets.

Chlorophyll content of the transport (Table 26) can be examined in terms of concentration (mg/m^3) or in terms of the proportion of the seston that it makes up (mg Chl/g AFDW). The latter is indicative of the relative importance of allochthonous vs. autochthonous materials. Chlorophyll density was consistently lowest during high runoff, reflecting dilution by water and allochthonous detritus. However, concentrations were highest at this time, as a result of scouring of

Table 26. Chlorophyll a concentrations and densities for the Mortar Creek Fire study sites.

Site	Date	Chl a (mg/m^3)	mg Chl a / g AFDW
TEAPOT	Mar 80	0.060	0.038
	Apr 80	0.165	0.073
	May 80	0.134	0.167
	June 80	0.033	0.020
	July 80	0.020	0.022
PUNGO	Oct 79	0.065	0.116
	Mar 80	0.096	0.165
	Apr 80	0.125	0.101
	May 80	0.102	0.208
	June 80	0.085	0.065
	July 80	0.095	0.236
E.FK. INDIAN	Mar 80	0.113	0.110
	Apr 80	0.136	0.014
	May 80	0.115	0.078
	June 80	0.099	0.057
	July 80	0.120	0.104
W.FK. LITTLE LOON	Oct 79	0.225	0.082
	Mar 80	0.400	0.534
	Apr 80	0.118	0.027
	May 80	0.087	0.029
	June 80	0.516	0.166
	July 80	0.182	0.126
CHAR	Oct 79	0.047	0.027
	Mar 80	0.132	0.165
	Apr 80	0.075	0.010
	May 80	0.254	0.065
	June 80	0.220	0.063
	July 80	0.318	0.303
LITTLE	Oct 79	0.038	0.043
	Mar 80	0.038	0.031
	Apr 80	0.370	0.036
	May 80	0.124	0.060
	June 80	0.377	0.128
	July 80	0.324	0.443
WHITE	Oct 79	0.051	0.127
	Mar 80	0.093	0.528
	Apr 80	0.116	0.037
	May 80	0.159	0.065
	June 80	0.115	0.052
	July 80	0.232	0.496
E.FK. LITTLE LOON	Oct 79	0.172	0.069
	Apr 80	0.102	0.008
	May 80	0.100	0.011
	June 80	0.558	0.134
	July 80	0.371	0.128

Table 26, continued.

Site	Date	Chl a (mg/m^3)	mg Chl a / g AFDW
MOUTH LITTLE LOON	Oct 79	0.147	0.115
	Mar 80	0.413	0.152
	Apr 80	0.370	0.014
	May 80	0.235	0.058
	June 80	0.678	0.050
	July 80	0.275	0.123
MARBLE	Oct 79	0.179	0.261
	Mar 80	0.487	0.218
	Apr 80	0.142	0.018
	May 80	0.203	0.220
	June 80	0.050	0.023
	July 80	0.086	0.045
BIG	Oct 79	0.326	0.384
	Apr 80	0.063	0.012
	May 80	0.424	0.102
	June 80	0.151	0.268
	July 80	0.143	0.239
MF INDIAN	Oct 79	0.205	0.214
	Mar 80	0.442	0.340
	Apr 80	0.432	0.054
	May 80	0.285	0.242
	June 80	0.132	0.102
	July 80	0.088	0.085
MF PINE	Nov 79	0.149	0.283
	Mar 80	0.470	0.672
	Apr 80	0.267	0.068
	May 80	0.306	0.093
	June 80	0.237	0.079
	July 80	0.095	0.067
INDIAN	Oct 79	0.153	0.202
	Mar 80	0.134	0.109
	Apr 80	0.236	0.047
	May 80	0.070	0.040
	June 80	0.054	0.037
	July 80	0.061	0.062
LOON	Oct 79	0.201	0.260
	Mar 80	0.811	0.612
	Apr 80	0.141	0.034
	May 80	0.404	0.056
	June 80	0.117	0.054
	July 80	0.075	0.078
MF DAGGER	Oct 79	0.276	0.233
	June 80	0.172	0.265
	July 80	0.159	0.084
MF LITTLE	Oct 79	0.115	0.153
	Mar 80	0.293	0.127
	Apr 80	0.379	0.045
	May 80	0.208	0.031
	June 80	0.096	0.046
	July 80	0.071	0.163
MF LOON	Nov 79	0.098	0.290
	Mar 80	0.371	1.009
	Apr 80	0.226	0.047
	May 80	0.226	0.095
	June 80	0.065	0.026
	July 80	0.0	0.0
MF MOUTH	Nov 79	0.097	0.271
	Apr 80	0.325	0.199
	May 80	0.927	0.084
	June 80	0.093	0.066
	July 80	0.162	0.124

the benthic periphyton, or immediately following runoff due to optimal light and nutrient levels. Visual examination of the substratum showed increased production of algae after runoff, some of which showed up in the transport. For the small tributaries minimum concentrations were similar in both the burn and control sites but maximum values were distinctly higher for the burn sites (0.3-1.6 mg/m^3 for burn vs. 0.2 for control streams). In spite of the scouring going on there, Little Loon Creek carried quite a bit of algae suggesting the presence of smaller relatively unperturbed tributaries like West Fork Little Loon higher in the drainage. Densities generally were highest during base flow when dilution factors were minimal.

Elemental analysis is another method for evaluating the potential food quality of suspended particulate organic material. Carbon and nitrogen analyses of selected seston samples have been tabulated for fall and spring in Table 27. Percentage nitrogen consistently exceeded 1% under autumn base flow conditions and was less than 1% during spring runoff. There were no obvious differences in percent nitrogen when streams of different size or fire history were compared. Percent carbon values for the small tributaries generally exceeded 30 while those of the main river were lower (23-26%) at least in autumn.

The C/N ratio provides an index to the nutritional quality of organic matter. The lower the C/N values, the higher the proportion of nitrogen and, by inference, the greater the protein content. All tributary C/N values exceeded 18 during both seasons whereas the main river values were always less than 18. The autumn main river C/N levels decreased progressively downriver from Dagger Falls (16.7) to the mouth (14.9). It is generally believed that consumer organisms

Table 27. Potential food quality of fine particulate organic matter as represented by carbon and nitrogen composition of transport at the Mortar Creek Fire study sites, Fall 1979 and Spring 1980. Values are means for three replicates drawn from single samples.

Site	Date	% N	% C	C/N
Teapot (C)	Oct 79	NS	NS	NS
	Apr 80	NS	NS	NS
Char (B)	Oct 79	1.30	34.25	26.32
	Apr 80	0.60	10.93	18.22
Pungo (C)	Oct 79	1.32	32.12	24.34
	Apr 80	0.38	8.36	22.16
	May 80	0.99	20.76	20.91
Little (B)	Oct 79	1.31	36.13	27.50
	Apr 80	0.86	21.99	25.66
	May 80	0.84	21.73	25.86
White (C)	Nov 79	1.47	35.92	24.49
	May 80	1.09	27.91	25.33
WF Little Loon (B)	Oct 79	1.43	37.60	26.27
	Apr 80	0.84	17.46	20.79
	May 80	0.99	24.18	24.38
Indian (C)	Apr 80	0.37	7.51	20.18
	May 80	0.21	4.82	23.49
EF Little Loon (B)	Oct 79	NS	NS	NS
	May 80	NS	NS	NS
Marble (C)	Oct 79	1.20	24.20	20.14
	Apr 80	0.02	1.69	137.60†
	May 80	0.14	2.83	20.06
Little Loon (B)	Oct 79	1.10	27.67	25.13
	May 80	0.03	0.64	19.12
Loon (C)	Nov 79	1.28	23.53	18.39
	May 80	0.12	2.46	20.15
MF Dagger (C)	Oct 79	1.57	26.16	16.66
MF Above Indian (B)	Oct 79	1.45	23.28	16.06
	Apr 80	0.89	15.67	17.53
	May 80	0.53	9.45	17.93
MF at Pine Flat (B)	Nov 79	1.57	24.24	15.46
MF Above Loon (B)	Nov 79	1.70	26.02	15.29
MF at Mouth (B)	Nov 79	1.58	23.55	14.86

†High value apparently a result of unusually low nitrogen percentage.

require a dietary intake of material with a C/N ratio less than 17. Therefore it is not surprising that the downstream decrease in C/N values is paralleled by a distinct increase in filter feeder standing crops (Table 13). However, although the two may be related the relationship did not hold consistently for the tributary streams.

SYNTHESIS

The Mortar Creek Fire study provided a unique opportunity to investigate the effects of wildfire on an otherwise pristine basin. In the future, with the establishment of the River of No Return Wilderness, limitations of funding, and modifications in philosophy concerning total fire suppression, fuel levels should return to more normal levels. This probably will result in fewer 10,000+ ha fires (Mortar Creek was 26,000 ha). Thus, the Mortar Creek Fire was as large as may be expected in modern times (= about a 500-yr event) and furnishes a rare chance to document the effects of this type of disturbance (isolated from the confounding factors) and to follow the subsequent recovery sequence.

In our proposal for the Mortar Creek Study we put forth a number of hypotheses concerning the responses of stream ecosystems to wildfire. These projected responses are illustrated and described in Figure 15 which is taken from the research proposal. The projections were made on a time scale of a century. Since we have examined only the initial stage of that sequence, we obviously cannot come to many definitive conclusions. Perhaps our most important accomplishment has been to establish a solid base for future reference. However, the initial effects of the fire were pretty much as we anticipated and, as we predicted, are immediate responses of the streams following the fire depended on stream size, burn severity, and precipitation/runoff conditions.

Figure 15

Projected responses of a stream ecosystem to wildfire. Immediate and long-term effects are illustrated by use of a logarithmic scale on the abscissa after the first post-fire year. These hypothetical trajectories illustrate anticipated changes in key physical and biotic parameters in low order (1st - 5th) streams of the Salmon River Basin. Actual values will be dependent on stream size, and edaphic influences such as watershed aspect, bedrock geology, severity of fire damage, and climatic factors such as precipitation and temperature. Asterisks indicate sample periods proposed for this study.

(a) Suspended sediment yield is normally positively correlated with discharge and follows the general pattern of snowmelt runoff (Fig. 2). A concentration increase in the months immediately after the fire is expected due to autumn rains. Snowmelt runoff should carry abnormally high suspended sediment loads, which will decrease annually as the watershed becomes revegetated. Occurrence of unusually high spring runoff or intense summer thunderstorms will cause short-term departures from this trend.

(b) For several years following the fire, nutrient output will increase due to the mineralization and leaching of elements which had been retained in the watershed in the form of forest biomass. During secondary succession, nutrient export levels are expected to drop below pre-fire levels as nutrients accumulate in the forest ecosystem (Bormann and Likens 1979).

(c) Incident radiation will increase as a result of the fire due to removal of riparian vegetation, and will gradually diminish as this vegetation recovers.

(d) Elevated light and nutrient levels will stimulate instream photosynthesis above pre-fire levels in these normally shaded, oligotrophic, headwater streams. Lower streamwater nutrient concentrations 5-10 years after the fire will contribute to the expected decline in autochthonous production.

(e) Organic litter input to the stream, including floodplain capture during runoff, will be elevated during the first year after the fire, but will decline until the riparian tree community returns (ca. 10-50 years).

(f), (g), (h) Responses of benthic invertebrate functional groups will vary depending on the degree of sedimentation which occurs. Heavy accumulations of fine sediments will eliminate the mixed cobble substrate prefered by endemic species, causing the response to be delayed until sediments are eroded and the benthos is recolonized. Shredder populations (f) will be reduced to near zero due to the destruction of quality leaf litter sources by the fire. Shredders should return when deciduous riparian litter inputs are reestablished (after year 10). Grazer density (g) will increase after the fire, following a pattern similar to that of primary production (d), on which they directly feed. Collectors (h), whose density is partially dependent on benthic and suspended food availability, will exceed pre-fire levels during the post-fire decade due to elevated levels of endogenous organic material.

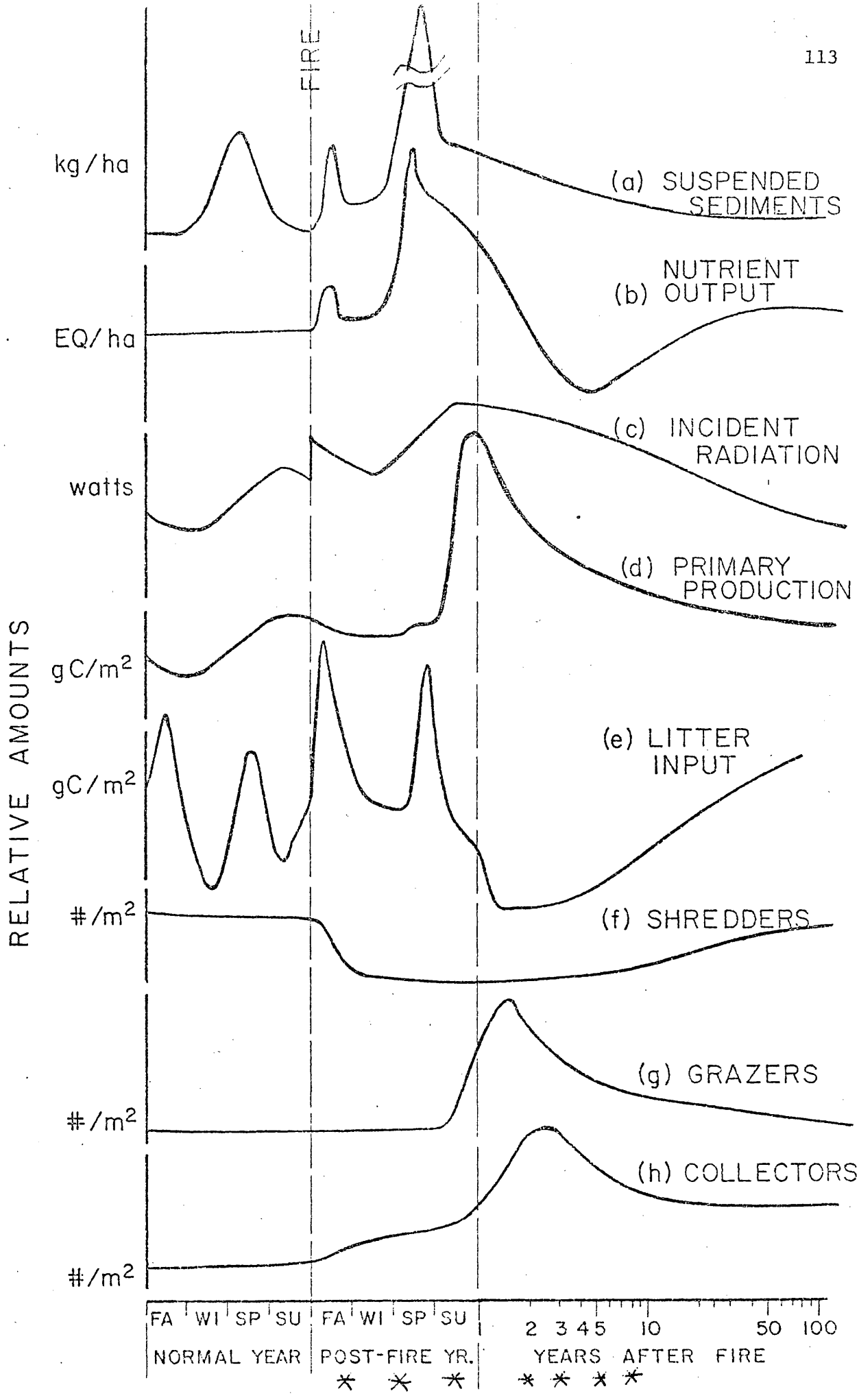


Fig. 15. Projected responses of a stream ecosystem to wildfire.

The post-fire, pre-runoff samples revealed some immediate impacts such as damaged moss and depressed invertebrate numbers in headwater streams (e.g., Char Creek), minor increases in sedimentation (e.g. Little Loon Cr.), and slight elevations in water chemistry. But in general there were no major adverse effects and the lotic community remained intact. Runoff had a variable impact on streams in the burned watersheds. The small streams appeared to carry greater than normal dissolved and suspended loads but the effects were not severe. There were no massive disruptions or sediment movements. For the most part, the normal retention mechanisms served to stabilize conditions in the burned streams. Little Loon Creek sustained the greatest damage. Heavy runoff and mass wasting of materials from destabilized side slopes blew out beaver dams and other retention devices, transported massive amounts of sediment, scoured the stream bed, and disrupted the biotic community. It also caused large amounts of sand and gravel to enter the main river.

The changes observed for Little Loon Creek came as a result of a "normal" spring runoff. However, the damage was magnified by a July flashflood which transported more sediment into the main river and carried a wave of particulate organic matter at least 150 km downriver (as reported by commercial boatmen). As a result of these runoff-triggered activities, the stream we sampled in July 1980 was anything but normal. There was a high sediment load despite near base flow conditions. There were low periphyton standing crops in spite of high light and nutrient levels and invertebrate numbers were low due to destruction of the benthic habitat. On the other hand, streams such as Char and West Fork of Little Loon Creeks with smaller drainage

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areas did not undergo extensive scouring and influx of sediments. They continue to support a healthy biotic community with good standing crops and high diversities of invertebrates and good algal production.

Except for the influx of sediments (whose importance may increase in the future), the Mortar Creek Fire has had little impact on the main river. For example, increased nutrients, such as nitrate, are being tied up in a short distance and their effect in terms of increased algal growth should be quite localized. Other nutrients like calcium and carbonates are buffered by the large volume of the main river and substantial preexisting concentrations. Much of the sediments transported by Little Loon (and now possibly by Little and Thomas Creeks) are sand-sized particles or larger which require high kinetic energy to remain suspended. They have dropped from suspension and settled in depositional areas within the main river (e.g. behind boulders, along the edges of the river) and will increase and be carried a little further downstream with each heavy runoff. The long-term impact of Little Loon Creek on the mainstream could be substantial. It is not unreasonable to expect a 1000-fold increase in sediment yield from the Little Loon drainage system. Also, the unstable banks and extensive source areas for new sediments suggest a long-term effect.

In general, the hypotheses presented in Figure 15 have been sustained at least as far as the immediate effects are concerned. The autotroph and invertebrate functional feeding group responses will take a few years to manifest themselves. But there is already substantially more light and nutrients in the burn streams than before

the fire so that a shift to endogenous food sources undoubtedly will occur. This appears to already have begun in the small streams. The grazers and collectors still may be expected to increase in these streams with a concomitant decrease in shredders and this trend will continue until the riparian vegetation becomes reestablished to the point where it provides a significant annual input of allochthonous litter. The small streams generally can be expected to continue to do well in the future provided they are not subjected to a severe runoff event (e.g. a severe thunderstorm). Little Creek was reported to have experienced a disruptive spate in September together with Thomas Creek but we have not had the opportunity to document the effects. However, as indicated earlier, with the data contained in this report we are in an excellent position to assess the damage done by this and future perturbations. Continued study would permit documentation of the recovery sequence and prediction of rates of recovery.

As noted earlier, extensive records of physical, chemical, and biological conditions of streams beginning immediately following a major fire are extremely rare and provide an invaluable reference base. Additional valuable information can be obtained by continuing the sampling program that we initiated at periodic intervals in the future. A minimum monitoring program would consist of samples of particulate organic matter, inorganic sediments, invertebrates, and water chemistry and measurement of autotrophic potential during summer or fall. Documentation of sediment removal rates would require additional sampling over the runoff sequence but measurement of sediment movement might be obtained through annual low-level aerial

photography. In addition, the importance of runoff events including thunderstorms have been emphasized by this study. To document these, good hydrologic records are necessary. Therefore it is strongly recommended that the stage recorder at Middle Fork Lodge be reactivated by the U.S.F.S. and that, as suggested at the beginning of our study, a recorder be installed at the mouth of Little Loon Creek.

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